Multitasking: The good, the bad, and the unknown

Cora M. Dzubak, Ph.D.
Penn State - York

Introduction

Multitasking is a term frequently used to describe the activity of performing multiple tasks during a specified time period. But what does it actually involve? Is multitasking the simultaneous engagement in various activities or is it sequential engagement in multiple tasks? Does it literally refer to actively performing more than one activity at the same time? Or, might it involve active engagement in a single activity while also passively processing another source of stimulation, such as auditory or visual input? Whichever it is, different types and levels of cognitive processing are required depending on whether tasks are performed simultaneously or sequentially. Can an individual simultaneously and effectively perform one hands-on task, visually monitor another one, while also attending auditorily to a third source of sensory input? In other words, does multitasking describe "engagement" in a single activity but also the frequent switching among several activities? Many people are certain they are performing multiple tasks at a specific moment in time. The above questions suggest the need for some clearer definitions and explanations of both multitasking and related information processing activities that are involved in the process. The first step is to define "multitasking".

Definitions

When asked to define multitasking, people very often describe the process of "doing two or more things at the same time". However, this simultaneous performance of multiple tasks is not consistent with the research based definition most often used for multitasking. Depending on the difficulty or complexity of the activities, it is very challenging to "perform multiple tasks at the same time" and still be able to effectively attend to and encode information associated with each task. The concept of "simultaneous" task engagement and processing of information needs to be distinguished from "sequential" task engagement, which is more characteristic of multitasking. It is the performing of multiple tasks sequentially and in quick succession that requires the need to examine other variables involved in attention and information processing.

For the purpose of this paper, multitasking is defined as the engagement in individual and discrete tasks that are performed in succession. It is implied that there is necessarily some time spent switching between tasks. The switching between tasks is a part of the sequential processing of information and necessitates the selection of information that will be attended to, processed, encoded and stored. Delbridge (2001) equates the switching between and among tasks with "attention switching". That is, it is not just a change in activities that is characteristic of multitasking, it is also a change in the individual's attention and focus. This requires an examination of the similarities and differences between task execution, or performance, and task switching. Simply changing between and among activities does not equate with execution of goals for those same activities; that is, "switching" and "execution" are separate cognitive functions.

Delbridge (2001) defined multitasking as accomplishing multiple goals in the same general time period by "engaging in frequent switches between individual tasks" (pg. 3). The individual may, at any given point in time, be making progress towards meeting only one of the goals but over the longer time period makes progress towards all goals. This definition is based on the assumption that tasks are performed in succession, or in a sequence, not simultaneously. Distinguishing between simultaneous and sequential processing, Delbridge (2001) noted that when trying to do just two tasks simultaneously, performance on one task is generally detrimental to performance on a second, simultaneous task. This distinction between simultaneous and sequential processing is significant in the research of multitasking.

Cognitive Processing Overview

Whether attempting to multitask by performing two tasks at the same time, or by switching from one task to another in rapid succession, there is a time cost associated with this kind of mental "juggling" or switching cognitive gears. Researchers conducted task-switching experiments in an effort to measure the "cost" or loss of time spent switching between activities. They also assessed how different aspects of the tasks, such as complexity or familiarity, affected any extra time-cost of switching. Some of the cognitive activities related to switching between tasks are discussed below.

Operating from definition that multitasking is engagement in frequent switches between tasks results in the need to examine related terminology and processes. Allport and Wylie (2000) described task switching as involving some kind of control switch that shifts the cognitive processing system from one configuration of task to another. They speculated that the types of control operations required to switch between tasks take time and should be detectable in the performance data, defining the time required to switch between and among tasks as "reaction time switching costs**".** In short, switching from one task to another requires a certain amount of time to cognitively "switch gears" since different parts of the brain and neural circuitry are generally needed for each separate activity. This "switching of cognitive gears" also involves a change in attention and focus.

Naveh–Benjamin, M., Craik, F., Perretta, J., Tonev, S. (2000) studied a related aspect of multitasking which is more specific to divided attention. Their research revealed "marked differences between the encoding and retrieval activities involved in processing the information created via multitasking." (Naveh-Benjamin, et al, p. 610). Although it was once believed that the same neural pathways were used during the perceptual processing of stimuli, their storage, and retrieval, it is now known that different neural pathways are used during these separate processes. The Naveh-Benjamin et al (2000) research demonstrated that encoding processes required more attention than retrieval and that the allocation of attention to encoding is under the subject's conscious control. These results demonstrated that "encoding processes are more vulnerable to the effects of competing demands" of multiple tasks (Naveh-Benjamin et al, p. 621). This point is especially significant when multitasking is discussed in the context of its impact on learning. Encoding is the first of three memory stages and involves the processes associated with receiving or registering stimuli through one or more of the senses and then modifying that information before it is stored. Naveh-Benjamin et al (2000) determined that the encoding processes are specifically disrupted by simultaneous processing; that is, doing two things at the same time (p. 621). His research findings indicate that divided attention at the point of encoding was shown to significantly reduce memory. It can be speculated that this disruption of the encoding process is likely to interfere with the amount and quality of information that is permanently stored in memory since encoding is the first of three memory stages.

In his research of individuals switching between two specified tasks, one of which was to be learned and stored in memory, Naveh-Benjamin et al (2000) was able to determine that as attention was switched to a secondary task and away from the first task, memory performance on the first task declined and secondary task performance improved. These findings are compatible with the Delbridge (2001) findings related to attention switching and the impact of distractions on our ability to process information. It is known that distractions effect task performance and this alone is important to the issue of multitasking because of the potential impact on learning and retention of information. However, a distinction needs to be made between active and passive distractions and their impact on learning and memory.

Delbridge (2001) noted that the impact of a distraction on memory depends on whether the distraction is active as in talking, counting or singing, or whether it is passive, as in listening to music. Not unexpectedly, active distractions have the potential to interfere significantly with what is processed and stored in memory. As noted above, when trying to perform just two tasks simultaneously, performance on one task is generally detrimental to performance on a second, simultaneous task But, a question to ask is whether distractions have the same impact on sequential processing as they do on simultaneous processing of sensory stimulation.

Delbridge (2001) found that through practice subjects were able to reduce the cost of task switching although they were not able to eliminate it. Unlike Allport and Wylie (2000), who examined the time it takes to switch among several tasks, Delbridge (2001) studied task switching from the approach of "attention switching". She noted that attention is limited and has some finite quality to it, and that an individual cannot attend to unlimited stimuli simultaneously. This suggests that "practice" and repetition of multitasking behaviors can improve one's ability. Delbridge (2001) noted that there are differences among people in multitasking performance and that some people are less susceptible to the process losses caused by multitasking or have an increased ability to handle them.

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The Impact of Multitasking on Cognitive Processing

Mutitasking and the Brain

There continues to be a significant amount of research identifying which parts of the brain are involved in specific information processing activities. It is known that the hippocampus is activated when declarative memory is used for processing context, such as information obtained from textbooks during reading or study. In contrast, a different part of the brain, the striatum, is used in the processing of procedural memory which is used for habitual tasks and activities such as bike riding or dialing a familiar number on the telephone. The types of processing that occur in these two regions are significantly different and impact storage and retrieval. The hippocampus will sort, process, and recall information involving declarative memory. Memories in the hippocampus are easier to recall in situations different from where they were learned, whereas those stored in the striatum are closely tied to the specific situation in which they were learned. It has been found that learning with the striatum while performing habitual or repetitive tasks leads to knowledge that cannot be generalized as well in new situations. (Poldrack as cited in Aratani, 2007) Having difficulty transferring knowledge from one situation to another is not consistent with the type of learning that we hope takes place in a college classroom and can be applied elsewhere and in the future.

The research of Rubinstein, J., Meyer, D., and Evans, J. (2001) is consistent with earlier studies finding that multitasking takes more time and involves more errors than focus on a single task. When learning with distractions associated with multitasking, students' brains are trying to "wing it" by using a region, the striatum, that is not best suited for long term memory and understanding. This is consistent with the findings of Delbridge (2001) who also noted that focusing on one task or a single goal results in fewer errors and less time than trying to focus on multiple tasks and goals.

Theories Related to Multitasking and Cognitive Processing:

Although the term multitasking is relatively new, many people might remember their first Psychology course and learning about D. E. Broadbent's (1958) dichotic listening experiment and the theory of "selective attention". That study involved research subjects attending to an auditory message directed to one ear while a second message was transmitted to the other ear. He found that there was little if any content from the nonattended ear that was remembered. Based on his findings, Broadbent proposed the theory of a limited processing channel (LPC) which explained that our neural circuitry has a restricted or limited capacity to deal with sensory input. This limits the amount of information that can be sent on to short term memory at any given moment in time. If information cannot be sent to short term memory, or if it is lost from short term memory, it cannot be forwarded to long term memory for storage.

As noted earlier, Wylie and Allport (2000) researched task switching as it occurred during the performance of two tasks. These were of equal priority and included little overlap between the two tasks. It was found that there was “proactive interference” between Task 1 and Task 2   That is, there was a need for processing time and changes in attention when switching between tasks. Wylie and Allport (2000) hypothesized that our executive control processes (ECP) may need to incorporate response monitoring and inhibitory mechanisms to cope with the interference caused by switching. This becomes a matter of “switching time costs” and involves two processes, 1) goal shifting, which requires keeping track of the current task as well as a future one and 2) rule activation, which requires identifying the stimulus, selection of the necessary rules to perform the task, and response selection needed to perform a second task**.**   The executive control processing model of interference is compatible with the Rubinstein et al (2001) attention-to-action model which he described as the cognitive supervision of the selection, initiation, execution, and termination of a task. In other words, the process of switching between tasks requires time.

The attention-to-action model developed by Rubinstein et al (2001) explains the development of cognitive schemas for specialized routines that involve well learned perceptual-motor and cognitive skills. It was found that a “schema, once activated, may actually suppress or inhibit activation of another” (pg. 88). For example, one might try to talk on the telephone while keyboarding, but to have a meaningful conversation while also trying to compose and type a meaningful sentence is difficult. That is, performance on one task, talking, suffers when one concentrates on performing the other (keyboarding). It is believed that task priorities and environmental cues are assessed via one’s supervisory attentional system which helps us to choose which cue will be responded to at any given moment (Rubinstein et al 2001). As we cognitively respond to a cue, the process begins of moving it through the sensory register to short term memory.

It was noted above that encoding is the first of three memory stages involved in processing information and is susceptible to the effects of distractions and limited attention. Hembrooke, H. and Gay, G. (2003) described what he termed a limited capacity model of attention similar to Broadbent’s limited processing channel which restricts how much sensory input we can handle. Hembrooke and Gay (2003) noted that “we have both conscious and unconscious mechanisms that determine what information is selected for encoding.” (p. 3). His findings serve as a strong reminder that although one might be exposed to sensory input from the environment that it does not mean that the sensory stimulation will be encoded and stored. Hembrooke and Gay (2003) interpretation of the experiments involving dichotic listening was that when the neural channel becomes overloaded, some of the information is filtered out, while other information is selected for further processing.   It was further noted that the finding of a performance decrement under divided attention conditions related to limited capacity is so robust as to consider it a guiding theoretical principle in the fields of attention, learning, and memory. Thus, based on the limited capacity model of attention, it was determined that there is a “fixed amount of cognitive resources upon which we can draw” (Hembrooke and Gay, p. 5) and it is our conscious and unconscious cognitive mechanisms and resources that determine what is selected for encoding and further processing.

In order for information to be effectively processed and stored after it is encoded, it must be moved into short term memory. It is generally agreed that working memory is the part of short term memory in which rehearsal of information and assignment of meaning helps to move it into the third stage, long term memory. Memory for new information is created through associations between the new and existing knowledge by recurrently activating and linking the bits of new information over time. In order for previous knowledge to be activated and linked with relevant aspects of the new, incoming information must be effectively processed in working memory. Our brain stores information by processes that involve organization and association of new information and experiences with those already stored in memory. Hembrooke and Gay (2003) noted that the greater the number of related associations between new and existing information over time, the stronger the memory. Any breakdowns in this process of encoding and storage of information reflect some misattribution of resources to the task at hand. Could this "misattribution of resources" be due to the divided attention characteristic of multitasking as well as the time cost incurred when switching tasks?

Rubinstein et al (2001) also described a strategic response deferment model of processing that explained when attempting to perform simultaneous tasks, our neurologic system has to activate a set of rules for Task #1, another set of rules for Task #2, and also give instructions about which task should be prioritized. Rubinstein et al (2001) later presented the Task Switching Theory, describing specifically how we go about switching from one task to another and the neurology involved in the "switching" between two or more activities. It is known that switching or alternating between activities involves "switching time costs" as task performance begins and ends and performance rules for each task change. It is the selecting and changing of task rules that takes time and begins to impact execution of the rules and task performance. Switching time costs become problematic when they conflict with the environmental demands for productivity and speed. Most readers can probably identify with trying to simultaneously have a phone conversation while writing an email. Inevitably, as one focuses on writing, a lag tends to develop in our verbal responses to the phone conversation.

Konig, C., Buhner, M., and Murling, F. (2005) more recently studied multitasking and also distinguished between sequential and simultaneous processing. Using simultaneous processing for the basis of his research, Konig et al noted that "in contrast to accomplishing tasks sequentially, in simultaneous multitasking the different tasks are very likely to interfere with one another." (p. 243). They studied several cognitive variables associated with multitasking and found that working memory, fluid intelligence, and attention are all predictors of successful multitasking. It was determined that interference in the performance of simultaneous tasks was a matter of resource allocation; that is, one of limited cognitive processing capacity. In short, our brains struggle to do more than one thing well at a time, especially if concentration is required and learning is expected. There is evidence that helps to explain why there are differences in one's multitasking skills; that is, why we are sometimes able to engage in more than one task at the same time while at other times that becomes problematic. In short, it depends on what we are doing and how much concentration and thought are involved.

Differentiating the Good, the Bad and the Ugly in Multitasking

Evidence from the Research

For over fifty years researchers have been interested in measuring how well an individual could execute competing task demands. As previously noted, Broadbent (1958) designed a dichotic listening experiment in which participants were instructed to shadow speech in one ear while ignoring a different message in the other ear. The results showed that there was little, if any, information retained from the message heard in the ignoring or non-attended ear. This is a frequently used example that demonstrates that dual input from the same sensory register, auditory, is difficult for us to process simultaneously. Channel overload, which is based on the research from dichotic listening, but in which it was found that we filter out some information while selecting some for continued processing. The important point to recognize here is that there is a limit to how much sensory input can be encoded, processed and stored.

Although initial research initially focused on the use of a single sensory register under competing demands for similar auditory tasks, Kieras and Meyer (1994) researched the processing of dissimilar tasks and found that sets of rules for two distinct tasks can be held in procedural working memory and used concurrently during multiple task performance. However, the rule activation stage of processing enables a set of rules for only one task at a time. One might speculate whether it is higher level supervision of task switching that interferes with performance, whether interference of one task on another causes switching time costs, or whether it is the combination of the two that interferes with execution of competing tasks. Meyer and Kieras (1997) speculated that "task switching may be mediated by a rule-activation stage of executive control through which the rules for prior tasks are disabled and the rules for current tasks are enabled in the execution of distinct operations" (pg. 69). More recent research has attempted to identify the cognitive processes involved in task switching and execution of the tasks.

The work of Hembrooke and Gay (2003) focused on the simultaneous processing of two competing tasks, one of which required use of visual processing and the other required auditory processing. It was found that "almost without exception performance on one or both tasks suffers a decrement as a direct result of having to perform the two tasks simultaneously."(p. 4). As noted earlier a performance decrement often results when task performance requires divided attention. This is due in part to the fact that the brain struggles to effectively perform two competing tasks at the same time. Hembrooke and Gay (2003) wrote that "the finding of a performance decrement under divided attention conditions is so robust as to consider it a guiding theoretical principle in the fields of attention, learning, and memory." (p. 4) The researcher noted that there is a fixed amount of cognitive resources upon which we can draw, consistent with previous findings regarding the limited capacity model of processing.

One of Hembrooke and Gay's (2003) studies involved students who were permitted to engage in computer browsing during a classroom lecture and found that there was a decrease in memory of lecture content by the browsers (p. 7). He found that "sustained distraction, regardless of context relevance, appeared to be the nemesis of the multitasker" (p 15). It was noted by Hembrooke and Gay (2003), however, that "if one is adroit at staccato-like browsing, processing multiple tasks simultaneously may not suffer to the same extent" (p. 15). Another finding from this study was that when students were specifically instructed to learn, they processed information in more elaborate and semantically relevant ways. Perhaps one's expectations regarding the level of information processing during multitasking determines how much concentration and attention are allotted and expended. This raises the question as to whether one can "practice" multitasking and minimize its negative impact on learning.

If that is the case, one might speculate that the "switching time costs" would be shorter when task rules are few and relatively simple, as compared with a task in which there are many complex rules needed for task performance. The executive control process includes goal shifting as tasks change, rule discontinuation when a Task 1 ends, and rule activation when Task 2 begins. The first stage of this process, goal shifting, keeps track of current and future tasks. Rule activation appears to be a more complex process since it requires identification of the stimulus, the disablement and activation of rules, as well as the selection of a response associated with the next task. It is logical to assume that the more "switching" that occurs between and among tasks, then the more time lost via "switching time costs." If, however, a person is simply switching from reading email, to checking for text messages on a cell phone, to clicking on MySpace.com, there are fewer rules to activate and certainly minimal need for in depth thought. This type of "superficial multitasking" can be done with minimal switching costs and no doubt improves with practice. But, does it interfere with learning if one of those multiple activities includes trying to do homework?

Some Conclusions Based on the Research: Differentiating the good, the bad and the ugly

The above overview of the research on multitasking provides sufficient information from which to make some summary statements. The results from Delbridge (2001) support a model of multitasking that included increased awareness of task switching that lead to increased stress levels, process losses, and lower performance results. It is known that when trying to perform two tasks simultaneously, performance on one task is generally detrimental to performance on a second, simultaneous task. The act of interrupting the original task includes an element of distraction resulting in interference and interruption. In cases where individuals switch between tasks their performance is worse than when they perform the same tasks individually. (Delbridge, 2001). The research provides quite convincing evidence that focusing on one task leads to better performance of that task as compared with alternating among various tasks.

Hembrooke and Gay (2003) wrote that "the juggling act of the information processor is to maintain a balance between what is required by the message and the distribution of already limited resources to process the information thoroughly." (p. 5) They noted that "all breakdowns in processing reflect some misattribution of resources to the task at hand" (p 5), again suggesting that focusing on one task maximizes use of available cognitive resources rather than fragmenting them via interruptions of task execution.

Although switching costs may be relatively small as individuals alternate between tasks, sometimes just a few tenths of a second per switch, they can add up to large amounts of time when people switch repeatedly back and forth between tasks. Thus, multitasking may seem efficient on the surface but may actually take more time in the end and involve more error. Rubinstein et al (2001) found that even brief mental blocks created by shifting between tasks can cost as much as forty percent of someone's productive time. Again, even though one might feel more productive when switching among tasks, research demonstrates that a large percentage of time is spent on the act of switching, requiring rule activation and disablement.

Poldrack (2006) described an attempt to transfer knowledge that was gained during activities performed while multitasking. He found that the subjects' knowledge was less flexible, meaning they could not extrapolate their knowledge to different contexts. The way they learned and the brain systems involved were different when multitasking as compared with focus on a single task. Multitasking, at best, appears to result in a superficial understanding of the studied material and that the active distractions involved in multitasking will reduce one's ability to learn, resulting in weak transfer to other settings.

Ben–Shakhar, G. and Sheffer, L (2001) found that the ability to perform dual tasks may become more automatic and less controlled with practice, and therefore its relationship with general cognitive ability declines. Hembrooke and Gay (2003) wrote that if one is skilled at browsing then processing multiple tasks simultaneously may not suffer to the same extent as it does for those less skilled. It is the sustained distraction regardless of content relevance that appears to be the major problem of the multitasker. It was noted that use of cell phones, IMing, and other types of media that change constantly "divide the mind" and interrupt study, more so than just background music, which can be soothing and helps students tolerate the quiet boredom associated with study. Whereas teens insist that these distractions enhance their study, Meyers suggests that multitasking has less to do with study help and more to do with study pleasure. That is, it is simply less boring to study when combined with other more pleasurable activities.

Tying it all together:

Do we get better at multitasking the more we do it? The answer appears to be that we do. Many of the college freshmen of today have practiced multitasking behaviors for years and are very skilled at it. But, does this mean that they are learning more? No, it does not. Does skill in multitasking mean that we will become better thinkers or problem solvers? No, it does not. Research has shown that although some learning was occurring while multitasking, it was less flexible, more specialized, and harder to retrieve when needed. It was also difficult to transfer, generalize or extrapolate the information to a different setting. If, however, information cannot be transferred or applied, it would appear to have very limited utility.

From research based on the use of functional MRIs it has been shown that different parts of the brain are used when multitasking as compared with focus on a single activity. This is because multitasking often involves repetitive behaviors and they are processed in the striatum rather than the hippocampus. However, if information is to be recalled and applied, it needs to involve the hippocampus, which plays an active role in long term memory. It has been shown that depth of thought and continuity of thought are disrupted when multitasking. One example of use of the striatum rather than the hippocampus is the following: You cannot recall a phone number from memory (hippocampus) but if you go to a telephone, you can punch the numbers in (striatum). That is due to the type of “habit learning” that takes place via the striatum. Under the circumstances of multitasking, habit learning can take over from declarative learning. But, is this really “learning”?

It is the switching of attention between tasks that is done in the anterior prefrontal cortex. This is what allows us to stop one task, start another, and then switch back to the first, as we do when we engage in sequential processing activities. Many aspects of perception and use of our senses, such as sight or hearing, can be performed in parallel with an action-planning activity, such as walking or driving. That is, some motor activities can be done in parallel. However, it is the “planning” part of the “action planning” that often must be done sequentially. For example, it is difficult to think of a meaningful response while on the telephone if you are also trying to compose a meaningful sentence as you sit at a keyboard. Or, if you are discussing a work related problem and also trying to write a meaningful paragraph about another, unrelated work problem, these tasks cannot be accomplish simultaneously. Instead, you will sequentially switch back and forth between the two tasks.

The theories and research presented above provide the reasons for why we experience dual task limitations; that is, executing or performing one task precludes beginning a second task. In short, there is cognitive interference when attempting to perform two tasks. If we do try to select two responses or engage in two activities at the same time, there will inevitably be a delay in the initiation of one of the tasks and getting cognitively reoriented after each interruption takes more time. The ensuing bottleneck results in a type of cognitive queing. That is, the neurology needed for the execution of the second task is delayed until use of the neurologic pathways from task one is completed. This “time cost” increases as the tasks become more complex and of they are too cognitively similar. Why? Because similar tasks generally require use of the same parts of the brain. This explains why driving and cell phone use sometimes interfere with one another but at other times the two seem quite compatible. Driving, unless very routine, takes thought, which is language based, and talking on the phone interferes with the “language” of thinking as we drive. For example, you might be able to talk on the phone with ease while following a familiar route, but if you suddenly approach the scene of an accident or an unexpected detour, the two activities conflict because of your need to think as you navigate past the scene of the accident or the unfamiliar detour. One might become quite skilled at the visual motor shifting required when multitasking among simple or familiar tasks, but this does not require the degree of thinking required when learning new information or problem solving!

Now What – Application

What, then, do students say about their multitasking behaviors? Many say that they do their “best work” while multitasking and that it helps them to feel less stressed. But, are they being more productive or do they just “feel better” while multitasking? After all, multitasking for most students is far less boring than uninterrupted focus on study. Young people and perhaps even many adults have become uncomfortable with silence and a lack of near constant environmental stimulation. Multitasking breaks the boredom. Does multitasking train the brain such that over stimulation has become the norm and we become uncomfortable when there is insufficient stimulation? If so, we then find it unpleasant to sustain undivided attention and prefer to be over stimulated. The state of cognitive over stimulation will typically interfere with the information processing needed for learning.

How can we use what is known about multitasking? First, there is a need to determine what tasks really should be completed with undivided attention; that is, initiation and completion without the interruption of task switching. Second, we need to recognize that when multitasking, our performance typically includes more errors and takes more time. Focus and attention are the keys to efficient and successful task completion. Finally, we need to encourage students to recognize that some tasks, such as studying or problem solving, are generally best accomplished without distraction or interference. It might be more pleasurable to multitask while studying but that does not correlate with more learning taking place. In the world of work there are ample opportunities to multitask and practice does appear to improve our multitasking skills. However, there is unequivocal evidence that depending on the task, degree of thinking, and the need for future application, we might want to do some things one step at a time, free of interruption, and do them well.

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