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# The Role of Working Memory, Self-Regulation, and Mindfulness in Multitasking Performance

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# The Role of Working Memory, Self-Regulation, and Mindfulness in Multitasking Performance

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# Abstract

## The Role of Working Memory, Self-Regulation, and Mindfulness in Multitasking Performance

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Abstract: This report lays out the ways in which multitasking has been defined and the component pieces of the process that can be improved. Changes to self-regulation, working memory, and heuristic thinking may lead to increased multitasking performance. Although working memory training has been varied in its results, the centrality of working memory capacity to task switching remains clear. Goal setting and goal monitoring might function to lower the cognitive load required for performing multiple interleaved tasks by helping to maintain conscious focus on the desired outcome. Additionally, mindfulness training has been shown to improve many of the cognitive functions involved in multitasking, and therefore it remains an area ripe for future research.

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# Chapter 1: What is multitasking?

The concept of multitasking has become a controversial topic particularly in our digital age. The term has risen to prominence in the digital age due to its origin in computer science. Multitasking was used to describe the abilities of computers to perform many tasks at once. The word was adopted to describe the human mind, but the meaning has become blurred from more colloquial discussion to its use in cognitive science. This chapter serves to differentiate the varied definitions of multitasking. Without a clearly defined meaning, discourses about multitasking conflate the issues of productivity and attention that are specific to different types of multitasking.

A plethora of research on multitasking has examined its effects on productivity. Generally, empirical research supports the notion that multitasking, for instance while studying or listening to lectures, decreases performance outcomes like reading comprehension or GPA. Moreover, this research supports arguments that regular multitaskers are likely to have larger deficits in performance than those who multitask less (Carrier, Rosen, Cheever, & Lim, 2014). Researchers found that high media multitaskers less selectively allow information into working memory, thereby allowing greater distractibility (Ophir, Nass, & Wagner, 2009). These types of findings have led educators to want to reduce multitasking in order to increase student outcomes. However, the decision to do so based on these findings represents an oversimplification of the research findings and the concept of multitasking itself.

Other researchers have discussed situational variation in terms of whether multitasking will be effective. Many have acknowledged the inevitability of multitasking instead of focusing on findings showing multitasking to be less effective. When multitasking is not broadly pinned as a bad habit with only negative outcomes, the ways in which it can be beneficial and the ways in which it might be best used or improved can be uncovered. For instance, although it is widely understood that tasks or combinations of tasks that overextend working memory will be less successful than those that do not, multitasking can assuage the boredom from a low arousal activity enough to have positive effects on productivity (Adler & Benbunan-Fich, 2012).

Further, research supports the notion that multitasking can spark creativity. In their study, Madjar and Shalley (2008) found that participants demonstrated their highest levels of creativity when they had goals for their tasks and had the discretion to switch between tasks. They suggested that the combination of focused analytical processes, when on task, and less focused processes, when completing a secondary or tertiary task, work in tandem for optimal creativity. The authors found that task goals lead to more focused attention on those tasks, and the discretion to task switch prevents cognitive exhaustion from that singular focus. Additionally, it is often the case that there is less time to accomplish tasks than they require. Multitasking may be the only path to an outcome in which all tasks are attempted to some extent.

Determining the measure of performance, therefore, seems to be a central component of assessing and improving upon multitasking. A helpful distinction that examines the seeming paradox between the experience of being more successful when multitasking and the continuous onslaught of research that cites the inability for a person to perform equivalently while multitasking and while monotasking is elucidated by Adler and Benbunan-Fich (2012). The authors wrote that when "performance is measured with productivity, different multitasking levels are associated with an inverted-U curve where medium multitaskers perform significantly better than both high and low multitaskers" (Adler, 2012, p.156). This description is in line with the experience of balancing several tasks and being more effective overall than when you limit yourself to only one. The authors go on to say that when "performance is measured with accuracy of results, the relation is a downward sloping line, in which increased levels of multitasking lead to a significant loss in accuracy."(Adler, 2012, p. 166) This is to say that pure accuracy, which is not always the objective, is always diminished the more that a person's focus is diluted with several tasks.

The more people avoid task switching and maintain focus, the more they are able to improve accuracy. However, even when people are asked only to remain on a single task, attention will falter. Even without secondary tasks, pilots told to monitor controls repeatedly exhibited mind wandering and distraction (Casner & Schooler, 2015). With this in mind, even single tasks have an attentional decay. Once attention has decayed significantly on a single task, adding a secondary task may actually refocus attention and improve both accuracy and productivity.

**The Spectrum of Multitasking**

If a person is presented with several tasks to complete within an hour they can take one of several approaches. They can focus on and complete each task in its entirety one after the next, a sequential strategy. They can try to concurrently complete the tasks, in parallel, but would be limited by their working memory capacity. Or, they can interleave tasks, making progress on one and then switching to another and back again. All of these paths to completion might be called multitasking because the person is completing multiple tasks in a short interval of time. However, some might argue that the first strategy should not be considered multitasking because it is successively completing several tasks. This though is really just an order of magnitude difference. The person is task-switching once every 15 minutes rather than once every 5 minutes. Additionally, if the tasks are interwoven in any way or refer back to each other, the sequential strategy most likely would become a version of the interleaved strategy.

The second strategy, that of simultaneously completing tasks, most likely would fall in one of two categories. Either what is happening is actually rapid task switching, attending to each component task back and forth second to second, or the two tasks could better be characterized as a single task because each task works toward the same goal and does not use the entirety of working memory.

The latter situation raises the question of what defines a task. If we don't consider simultaneously breathing and walking multitasking, where do we draw the line? Poposki & Oswald (2010) defined a task as a "discrete set of activities engaged in for the purposes of attaining a goal" (p. 250). The component of goals is a central point to defining tasks as is the concept of cognitive load. *Cognitive load* is the mental effort being used in working memory. A further way of distinguishing tasks then would be based on the amount of cognitive load they require. An example of how these two pieces interplay would be organizing for a party. Although the component parts of preparing for a party have a singular goal, the cognitive load required for baking a cake, decorating the house, and making a playlist is beyond that of a single task. Conversely, if someone were to listen to a podcast while doing the dishes they could distinguish two goals, but together they may not reach the maximum capacity of working memory, and therefore that would not necessarily constitute task switching, similar to dancing and listening to music.

Instead, this behavior could be considered a complex action when a task is defined as something that requires a higher portion of working memory than activities that could be easily done concurrently.

Looked at in this way, these different categories of multitasking could actually all fall under the "interleaved" strategy with the difference between types of multitasking being a continuum of the time spent on each task before switching. Therefore the interleaved strategy for completing tasks will be part of the definition for multitasking in this paper. Additionally, the way in which *task* is defined is important to the definition of multitasking in this paper. What goal defines the importance of a given task? How much of a person's working memory capacity (WMC) will be used? Below is a chart that clarifies several of the types of multitasking that arise from these distinctions. Ways to optimize performance in all of these types of multitasking will be laid out in this paper.

| Time | Goals | Example | How | Why |
|---|---|---|---|---|
| Concurrent/parallel (must be two things below the threshold of WMC) | Same | Doing a tour of a city by Segway | Both tasks require less than the full WMC. | This is also a "complex action" or a task that requires multiple modalities. |
| Interleaved task-switching (quick) | Same | Note-taking in a lecture | You quickly switch your attention between writing and listening. | This is in order to best reach the overall goal of comprehending and remembering the lecture. Perhaps you could perform better on a test of lecture comprehension by simply listening, but you may not remember it weeks later without notes. |
| Interleaved Task-switching (slow) | Same | Preparing for a party | You have a complex goal and many steps to get there. You juggle the intersecting time constraints of all aspects of the complex goal. | Perceptual grouping serves to create an overarching goal, with which one would organize and allocate time and energy to each subtask. |
| Concurrent/ parallel (must be two things below the threshold of WMC) | Competing | Listening to a podcast while doing dishes | Both tasks require less than the full WMC. | To avoid the boredom of a single task or to more effectively use the empty space in WMC. |
| Interleaved Task-switching (quick) | Competing | Texting while in a lecture | You quickly switch focus between texting and lecture listening which could jeopardize successful comprehension if the material is complex. Conversely, the student may task switch only during lulls in the lecture. | To avoid the boredom of a single task or to manage competing goals. |
| Interleaved Task-switching (slow) | Competing | Writing a paper and finishing a problem set for math | You switch between these tasks when you hit a low point in focus or when the urgency of one goal supersedes the other. | To manage competing goals. |
| Complex identity | Competing | Doctor and mother | The delays between the tasks switches may be long or short but would involve balancing the urgency of goals. | To manage competing goals. |

Table 1. Time and Goals in Multitasking

How does the time between switching tasks affect multitasking performance? How do the goals of each task and the organizational structure of the task switching further differentiate types of multitasking? How should task difficulty, number of tasks, or individual differences in preference for multitasking be taken into account when examining multitasking? This section will address these questions, but it should be noted that many researchers take different stances on these questions. Therefore, results of multitasking research should be compared while keeping these differences in mind.

**The Process of Task Switching**

What is actually happening as we switch between tasks? One central theory in multitasking research is called threaded cognition. Essentially the theory is based on several key assumptions, the first being that cognition maintains a set of goals that lead to goal driven processing given known resources. The second assumption is that all resources, which can be cognitive, perceptual, or motor, will complete tasks "serially" or successively. These threads, or task goals, do all of the allocation of resources, according to threaded cognition theory, claiming the resources until finished and the next thread pulls for the resource (Salvucci & Taatgen, 2008). The fact that this theory contends that individual threads pull for resources rather than being allocated by central executive commands raises the centrality of task-level goals in propelling behavior.

When resources shift away from a task, there must be a system for maintaining the process in memory. There is a conscious process of rehearsal that people use when they successfully task switch. Metaphorically, a rehearsal would be a bookmark we use to hold our place in a task while we begin to work on a secondary task. An example would be if someone were playing a video game (primary task) and then decided to go help a friend with moving a piece of furniture (secondary task). The person would rehearse their place in the video game so as to resume it with maximum efficiency. They would rehearse the primary task again when doing the secondary task as well if the primary task was difficult enough. Then when it came time to resume the primary task, the rehearsed representation of the task would be recalled in order to continue the task without the delay of having to reorient oneself. Part of the studied decrease in accuracy when multitasking comes from the interference of the rehearsal. The cognitive load of this rehearsal varies depending on the level of the task. For example, one could imagine that depending on the complexity of the game or its story line, the amount of interference from rehearsal could vary significantly.

One line of research that supports this idea of rehearsal comes from studying the differences in outcome when people are either warned that they will be switching tasks or are switched from the primary task without warning (Trafton, Altmann, Brock, & Mintz, 2003). Participants in the no warning group take longer to resume the primary task because they did not rehearse the primary task as thoroughly as the warned group, as measured by verbal reports. When a person is interrupted from a task, for instance when a person knocks at the door while at work, they lose the ability to rehearse the primary task being worked on, and therefore may experience a more significant interruption lag than if that person had decided to self-interrupt (Salvucci & Taatgen, 2008).

From this line of thinking we can begin to consider the types of scaffolds that would be most useful at reducing the switch costs involved in multitasking. Salvucci & Taatgen (2008) explained that the process of rehearsing and recalling tasks while switching from and switching back to that task causes interference that reduces the speed of the event. Additionally, the cost of one's memory for a secondary goal causes interference in the working memory that could be offset by particular scaffolds.

Salvucci & Taatgen (2008) also discussed the effects of task relatedness in reducing interference from secondary tasks. Related secondary tasks led to comparatively smaller interruption processing and smoother original task resumption. This relates to the way in which people are able to attend to multiple pieces of information at once if they perceive the separate bits of information as a coherent, singular message (Bergen, Grimes, & Potter, 2005). This concept, called *perceptual grouping*, diminishes the production and maintenance of a representation for tasks or pieces of information and therefore reduces the overall cost on cognitive load. For instance, for this reason, individuals would be more effective at switching between two screens of basketball games than a screen of basketball and a screen of soccer.

These findings lead to the question of how perceptual grouping might vary from person to person. It also warrants the question of how certain representations at a basic level could be taught to learners that would help them to interrelate tasks and concepts. How might one's tendency to group information perceptually lead to an increase in performance in multitasking situations?

**Not Procrastination**

Another way in which discussions of multitasking can be obscured is when it is confused with the concept of procrastination. Successful multitaskers are not necessarily people who avoid procrastination. Activities which people engage with to procrastinate are often the same ones that they engage with when multitasking. This is most likely where the confusion arises. For instance, when an employee is emailing clients while in a meeting, this would be considered multitasking because the meeting will continue regardless of one's level of attention. If that same employee decides to email clients instead of working on a report this could be considered both procrastinating or multitasking depending on why they chose to email, was it to perform the multiple tasks necessary for their job more effectively, or to avoid the more urgent report writing. If the emailing was less urgent than the report, and the employee was emailing only to delay the completion of the report, perhaps due to difficulty, then this would be procrastination. Here it becomes clear that the difference between procrastination and multitasking is the motivation behind it combined with whether or not it can be delayed.

A cousin to procrastination is distraction. Distraction is procrastination when the primary, goal-directed task is time-bound. For instance, if one were to text while in a lecture this would be distraction because the lecture is not pushed off by the secondary task but avoided by it. When the time-bound task is the secondary, non goal-directed task then this would be procrastination. If one were to watch a movie while studying for an exam, this would be a form of procrastination because the primary goal of studying is knowingly undermined by the secondary non goal-directed movie watching.

Clarifying and separating procrastination from multitasking is necessary because multitasking that happens as a result of procrastination is not goal directed, or is at least goal subversive. Without goals, tasks become unstructured and unwieldy. For instance, if one were to switch to reading the news while working on an assignment, the news reading has no bounds by which to indicate successful completion. Therefore, its purpose actually becomes avoidance of the primary task rather than the news reading having a goal for its own sake. Procrastination as a form of multitasking cannot be improved upon except in its reduction, and thus it will not be discussed further in this paper.

| | Activity | Motivation | Time Limitation of main task? | Classification | Possible Cause |
|---|---|---|---|---|---|
| 1. | Emailing intermittently while writing a report | Avoidance due to difficulty/boredom | No | Procrastination | • Task difficulty<br>• Inability to focus<br>• Wanting to focus on present moment enjoyment |
| 2. | Emailing intermittently while sitting in class | Avoidance due to difficulty/boredom | Yes | Distraction | • Task difficulty<br>• Inability to focus<br>• Wanting to focus on present moment enjoyment |
| 3. | Emailing intermittently while writing a report | Responding to emails in a timely manner/balance consideration of the job | No | Multitasking | • Balancing goals<br>• Time awareness<br>• Priority evaluation |
| 4. | Googling information about artwork while at a museum | To enhance the experience of the overall goal of art appreciation. | No | Multitasking | • Boredom with basic task<br>• Desire to deepen understanding |

Table 2. Motivation and Classification in Multiasking

**Task Difficulty**

Another significant variable in the realm of multitasking is the difficulty of the task. When a singular task takes all of a person's attention to complete, multitasking detracts from overall performance. When tasks are less demanding, multitasking increases overall performance. This line of thinking was tested by Adler and Benbunan-Fich (2013). In their study, they found that when subjective evaluation of task difficulty was higher, participants who were forced to multitask did significantly worse than those who did not multitask as well as those who were able to multitask at their discretion. This is in line with the hypothesis put forth in the Madjar & Shalley (2008) study that found that discretion to task switch decreased the likelihood of cognitive exhaustion from a difficult task.

Most notably, Adler and Benbunan-Fich (2013) found increased performance in participants who were forced to multitask over both those who did not multitask and those who multitasked at their discretion when the primary task was subjectively easy. This finding underscores the importance of task difficulty in determining when multitasking would be most effective and when it would lead to deterioration in task performance.

From these lines of literature, multitasking is most ineffective when task difficulty is high. High difficulty task switching would be most effective with longer intervals between switching. In fact, discretionary task switching is normally done at low cognitive load points (Adler & Benbunan-Fich, 2013). Therefore more difficult tasks would be less likely to induce task switching.

**Yerkes-Dodson Law and Multitasking**

The Yerkes-Dodson law explains that performance is a function of arousal and task difficulty. Performance is an inverted-U function of arousal, with performance improving with increased arousal until arousal hits an optimal level. After the optimal level of arousal, increased arousal negatively impacts performance. In terms of task difficulty, easier tasks require more arousal to hit the optimal level for maximum performance than more difficult tasks do (Anderson, 1994).

The Yerkes-Dodson law was used as an explanation by Adler and Benbunan-Fich (2012). They hypothesized that cognitive switching costs from multitasking actually increase arousal to an optimal state when task difficult is low, presenting as efficiency gains by participants. In high task difficulty groups, the cognitive switch costs increase arousal past the optimal level and actually present as interference in performance outcomes (Adler & Benbunan-Fich, 2012).

Arousal effects also matter more when people are asked to manage multiple goals. Lee, Jin, and Robertson (2012) studied reading comprehension in three conditions: reading in silence, reading with a non-tested video playing simultaneously, and reading with a video playing simultaneously that would include a test of video content subsequently. Their results were that reading in silence and reading with an untested video had significantly better results than when the video was tested. Notably, it was having the singular goal of performing well on the reading task that differentiated performance. When participants had two goals, the diffuse focus inhibited performance (Lee, 2012).

Rapid, flitting task switching is normally not effective because it does not provide a person with a large enough chunk of attention. However, when task difficulty is low enough, this flitting might actually enhance performance. As task difficulty increases, the level of arousal, which would consist of the task itself, task-switching costs, and outside distractors, must be kept low in order to perform optimally. It would follow that research in multitasking performance should need to distinguish whether individual differences in optimal arousal have significant effects on outcomes.

**Individual Differences**

There are several individual differences that have been considered when examining multitasking performance. Polychronicity is an individual difference variable that measures people's preference for multitasking, but it is not a measurement of success at those tasks. Poposki and Oswald (2010) developed a Multitasking Preference Inventory (MPI) and found that scores on the MPI positively correlated with Extraversion and polychronicity. They also hypothesized that highly polychronic individuals may derive more personal fulfillment from of jobs with more multitasking (Poposki & Oswald, 2010). This leads to the question of whether more extraverted individuals may prefer multitasking because of a higher need for arousal.

Kirchberg, Roe, and Van Eerde (2015) looked at on the job multitasking through diaries with the purpose of uncovering individual differences in preference for multitasking and the necessity of opportunity and unplanned interruptions in the use of multitasking. Within self-identified low and high polychronic individuals, they found that in low multitasking environments, low polychronic individuals had higher task performance than high polychronic individuals. In high multitasking environments, high polychronic individuals outperformed low polychronic individuals. Additionally, polychromic individuals' affective well-being and self-rated performance were less affected on days with high levels of multitasking (Kirchberg et al, 2015).

Another important individual difference is organizational tendency. Britton and Tesser (1991) did a study on college students that found that two time-management components, Time Attitude and Short-Range Planning, accounted for more variance than SAT scores in cumulative GPA. Short-Range Planning included items such as, "do you make a schedule of the activities you have to do on work days?" and "do you set and honor priorities?" Time Attitude included items such as "do you make constructive use of your time?" and "do you continue unprofitable routines or activities?" (Britton & Tesser, 1991).

The reasoning behind this research stemmed from the notion that college students juggle many demands and expectations on their time. Britton and Tesser (1991) argued that those participants who score higher on time-management would therefore be more successful at undertaking the complex task of being a student beyond the traditional effect of aptitude as measured by SAT scores.

However what would these management scores mean in terms of juggling several tasks in one short period, say one hour? Does management of tasks over months relate to how people manage tasks in terms of hours? Terry (2015) looked at college students as well and found a strong negative correlation between time and study environment management and preference for multitasking. Further, students who reported greater time and study environment management also reported a lower preference for multitasking.

Taken together, it might be concluded that multitasking less is the best strategy for positive outcomes. However, what really may underlie the difference is successful multitasking. It should be noted that Terry's (2015) study looked at media multitasking, which may overlap significantly in its definition with procrastination multitasking, like watching a TV show while studying. What is significant to take away from his findings is that there is an important relationship between personal organizational structures and multitasking.

**Conclusion**

Understanding the concept of multitasking and performance requires getting clear about what we mean by multitasking and what we mean by performance. Because so much of the way we multitask in the 21$^{st}$ century is mediated by technology, determining optimal outcomes can lead to better systems for computer-mediated task switching. Further, educational and employment outcomes are at stake. People equipped with devices are necessarily going to have the opportunity to undertake countless tasks every minute of the day, but determining what defines effective multitasking and what qualifies as distraction can make the way we teach and organize more appropriate given the reality of device use.

In exploring the definition of multitasking in this chapter, several concepts arise for more in depth discussion. In light of the impact of arousal on cognitive load on multitasking, this report will explore working memory capacity and its improvement to determine if improvement in task switching might begin there. With increased working memory capacity, more actions can be done in the concurrent realm of a singular attention span. Secondly, the concept of goals and organization repeatedly occur in the discussion of task switching. Thusly, goal setting and self-regulation will also be reviewed.

## Chapter 2: Working Memory Capacity and Its Improvement

This chapter outlines the way in which working memory capacity impacts multitasking as well as ways to improve working memory effectiveness. Whether a person completes a single task or multiple tasks, they are subject to the limits of their working memory. Additionally, working memory and self-regulation, which will be discussed in the next chapter, are inherently intertwined with working memory capacity limiting the amount of self-regulation that may be possible. Thus, a thorough understanding of working memory and its limitations is vital to helping elucidate how self-regulation can influence multitasking performance.

Across the literature, working memory reflects a variety of influences, but all include the ability to control attention. Working memory can be defined as "the ability to keep attention focused on one thing and not let it be captured by other events, be they in the external environment or internally generated thoughts and feelings" (Barrett, Tugade, & Engle, 2004). Once working memory is defined in this way, we can further define working memory capacity as the individual difference in space for the processes that take place in working memory. Individual differences in ability to control attention define when multitasking moves from effective to ineffective. If someone takes only moments to center and focus, task switching is less detrimental to overall productivity. Working memory capacity is measured in several ways. For instance, individuals may read sentences out loud, with each sentence followed by an unrelated word. After reading the last sentence-word combination, participants try to recall the list of unrelated words. The higher the recall, the higher the WMC score (Baron & Ward, 2004). Additionally, counting span, operation span, and reading span tasks are often used to measure WMC (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle 2005).

Working memory is the location of all conscious cognitive processing, and it can engage with only a limited number of novel interacting elements (Paas, Renkl, & Sweller, 2003). Thus there are two ways to go about affecting the amount of processing that can be done via working memory: increase WMC itself, or relegate what would once have to be done in conscious processing to automatic processing. Essentially, all human thought happens via automation. Most basic processing an adult does could not be done without the existence of complex schemas that underlie them. Schemas, which are stored in long-term memory, contain once automated processes that, prior to automation, would have filled most of working memory capacity. For instance, if an adult were asked to write numbers 0-100 by 5, they would have to access the schemas for 5's counting and for writing itself. By comparison, most kindergarteners doing the same task would have difficulty due to limitation on working memory. They would most likely have to count on fingers to each 5, which would consume the majority of their working memory. This can be understood by examining the contributing factors to cognitive load that define the stressors on WM.

According to cognitive load theory, cognitive load has three components: intrinsic cognitive load, extraneous cognitive load, and effective cognitive load (Paas et al, 2003). Intrinsic cognitive load is the base load of any task that can be reduced only by schema creation and subsequently schema automation. As we learn how to write, the task of writing moves from a conscious process that exacts a heavy burden on intrinsic cognitive load to a writing schema that can be processed automatically. Thus, a consequence of learning is lessening cognitive load and making space for more complex processing. Extraneous cognitive load is any unnecessary additive to a task that does not impact the automation of the processes that underlie intrinsic cognitive load. For instance, in the example of writing numbers by 5, if the instructions to the task included using a blue marker in the room to write the numbers with but the location was not explicitly written, the cognitive load needed to solve for the location of the marker would constitute extraneous cognitive load. Lastly, effective cognitive load is the opposite of extraneous cognitive load in that it facilities schema acquisition rather than impeding it. An example of effective cognitive load would be giving a number line to aid the kindergarteners in completing the about task.

The hypotheses of cognitive load theory fit well within dual-process theory which divides our thoughts and actions into two types: automatic processes (nonconscious, implicit, heuristic) and controlled processes (goal-directed, top-down, endogenous attention) (Barrett et al, 2004; Hofmann, Gschwendner, Friese, & Schmitt, 2008). Cognitive load theory proposed that intrinsic cognitive load can be reduced with schema creation, and dual-process theory further describes the way in which controlled processes (intrinsic cognitive load) and automatic processes (schemas) work together. The process of automating tasks is central to the understanding and differentiation of multitasking.

Considering the dual-process model, both the conscious processing that occurs in working memory and the automatic processes that occur in schemas and long-term memory should be looked at as potential places to improve multitasking performance.

**Improving WMC**

Improvement to working memory capacity is one way of increasing multitasking ability, as more complex processing can be done within a singular attention span. Konig, Buhner, and Murling (2005) found that working memory was the most important predictor of multitasking performance, and it explained a significant amount of variance that could not be accounted for by fluid intelligence, although the two were highly correlated. Their results showed that fluid intelligence and attention were also important predictors; however, multitasking performance was not related to polychronicity nor to extraversion. These results further underscore the need to research ways to increase WM in order to better perform in multitasking.

There have been numerous studies that have pointed to WM training as having effects on WMC. Harrison, Shipstead, Hicks, Hambrick, Redick, and Engle (2013) demonstrated that training on complex working memory span tasks led to improvement on similar tasks with different materials but that such training did not transfer consistently with different working memory capacity tasks, and did not transfer at all in tasks that measured fluid intelligence. Olesen, Westerberg, and Klingberg (2004) found fMRI evidence for an increase in prefrontal and parietal area activity after working memory training.

Morrison and Chein (2011) reference the debate around whether WM even has a capacity limitation, or whether performance differences might actually be due to interference. They go on to outline methods of training that take these different ways of improving WM into account. With strategy in mind, there is training that promotes domain-specific memory techniques, like word association and mnemonics. There is also "core training," which uses WM tasks that are non domain-specific to increase the underlying WM mechanisms.  Harrison & Shipstead (2013) used complex span and simple span training working memory. In complex tasks, individuals must complete a simple processing task like a mathematical operation between simple span task items. This requirement of memory while exposed to distraction highlights the centrality of attention in WM.

These different training approaches demonstrate the complex nature of WM and often serve to obfuscate the meaning of the results. For instance, domain-specific memory strategies may actually be a process of automating previously controlled processes rather than increasing the space for conscious cognitive processes. When working memory capacity training includes strategies like chunking, rehearsal, or creating a story with discrete pieces of information, what is most likely occurring is the automation of the process (Morrison & Chein, 2011). Further, with working memory training, researchers have found improved cognitive control "among a small cohort of children diagnosed with ADHD, and a concomitant reduction of ADHD symptom severity" (Morrison & Chein, 2011). These results could best be explained by a relegation of more components of conscious processes, which would be more stimulating to individuals with ADHD, to automatic processing.

Dux, Tombu, Harrison, Rogers, Tong, & Marois (2009) studied the effect of training in multitasking situations on the neuronal pathways involved. They found that training did not divert processing from the prefrontal cortex or segregate task-specific pathways; instead training increased the speed of processing in the prefrontal cortex to allow for rapid, successive processes. They proposed one hypothesis that decreased use of the attention center of the brain after training and reduction in multitasking interference with training can be largely explained by improved performance on each of the two single tasks. (Dux et al, 2009) However, their fMRI results showed that this actually happened via reduction of activation in the inferior frontal junction (IFJ), the area that showed increased activity in dual-task versus single-task trials prior to training. The authors argued that this supports the hypothesis that the IFJ is responsible for response selection, and training shortens the response selection for each task. Another way of understanding the finding is that there is a central bottleneck for information processing in the IFJ, and when this stage of the task can be sped up via training, the dual-task event can happen more quickly. However, it also suggests that there is a limit to the amount that training can accomplish due to the fact that there is a single pathway through which all processing must go. Metaphorically, this would be equivalent to a single lane of traffic where cars can drive faster, but a second lane will not be opened.

That WM training may actually be improving certain performances via automation could explain some of the convoluted results. Shipstead, Redick, & Engle (2012) did a review of several working memory improvement papers. These studies looked at the effects of WM training on very similar WM tasks (near transfer), different WM tasks (moderate transfer), and fluid intelligence task  (far transfer). Although some of the studies found significant effects for transfer of WM training to some of these secondary tasks, the authors wrote that much of the has demonstrated conflicting findings. The authors' conclusion from examining the research is that research needs to include several measures of abilities of interest because none of the single tests have shown an undisputable ability to be replicated. Secondly, they recommended that the focus with WM training be near transfer to other WM capacity measure, different from the method of training, and WM training should first impact WM and subsequently fluid intelligence or attention. Lastly, they argued that studies should use an active rather than no contact control group and that raters should be blind to the condition assignment.

From all the conflicting evidence, it can be assumed that increases to WMC should be looked at with cautionary eyes. Thus, a focus on improving working memory capacity should be a future pursuit but not the primary way for improving multitasking performance. Instead, reduction of the cognitive load on working memory through automaticity should be a more central emphasis for improving multitasking performance.

**Dysfunctional Automation**

If working memory capacity refers to one's ability to give attention to what it is important and to suppress the unimportant, the process of consciously developing and perhaps reworking created schemas is vital. As mentioned, working memory capacity is something that can vary person to person. Someone with a large WMC has more "space" to work on controlled processes than someone with a lower WMC. That is, if someone is tasked with something complex like running a company with 1000 employees, there is more than enough processing that *could* be done in a conscious way, but the person must relegate some of these processes to the automated section of our brain because there is too much to do. The automated processing depends on stereotypes and previous patterns to work, which may be ideal for driving, but may be less so in other settings.

One reason for this is that in controlled processes a person can compare their pre-set goals with actual outcomes. Therefore, in controlled processes we can re-evaluate, fine-tune, and work toward goals. Automated processes may work seamlessly at times, but the challenge is creating better automated processes. Because automated processes depend on the patterns we develop while we consciously process when there is less vying for our attention, those conscious processes end up having a multiplied impact. Deliberate work in the preceding conscious  processes will lead to automated processes that work well and are aligned with a person's larger goals.

The larger one's WMC the more that can be done consciously, which presumably leads to better multitasking results as dependence on automation is less central. For instance, Hofmann & Gschwendner (2008) wrote that consumption of tempting food happened more often in people with lower working memory capacity.  Automatic attitudes toward the temptation had a strong influence on behavior for individuals with lower WMC. Controlled dispositions such as explicit attitudes and self-regulatory goals are more effective in guiding high WMC participants.

Learning new things is dependent on working memory whereas habit formation is less dependent on working memory (Lin, Robertson, & Lee, 2009). New tasks require a higher cognitive load, so once a particular task is mastered, it has a lesser effect on cognitive load and thus working memory. Increased automatization decreases the difficulty of a task and allows the executive control to re-allocate attentional resources (Macnamara, 2012). Cognitive load is steepest when learning new tasks that have not yet been automated (Feldon, 2007).

Feldon (2007) reported that more experienced teachers are relieved of many aspects of cognitive load that new teachers experience as mentally taxing. Because teaching is an inherently multitasking oriented career, this example is one in which positive and negative forms of automation can be distinguished. In the case of teaching, certain aspects of classroom management or content understanding would become automated over time to allow teachers to open up space within their working memory for other processes. Moving these processes from intrinsic cognitive load to schemas enables experienced teachers to demonstrate enhanced multitasking ability. This research helps to reveal that "tasks" that originally placed heavy burdens on cognitive load could eventually become as automated as gum chewing.

On the other hand, some experienced teachers may have automated certain processes that negatively impact their teaching. For instance, if due to high cognitive demands, a teacher automated stereotypes as a component of classroom management or misconceptions as a component of content knowledge then these schemas would become more deeply entrenched in the teacher's behavior than controlled processes would have been. Based on an unconscious schema, these adverse behaviors are more difficult to change.

Voss, Prakash, Erickson, Boot, and Basak (2012) looked at novice videogame players learning a new game. One group was asked to focus on all aspects of the game during learning and the other was told to focus on improving separate components of gameplay in the context of the game as a whole. They found that the second group, which was focusing on separately learning each skill in the game, learned most. This study took a multitasking event and showed that providing a strategy that prioritized "variable priority" training, thereby combining emphasis and integration, enabled formation of efficient, automatic schemas to initially effortful pieces of the task. This strategy for automaticity induction is telling. When each component piece of a complex task, like the teaching example, is consciously and deliberately focused on, the automation is more likely to be functional and thorough.

Clearly, automation can be maladaptive in certain circumstances. When interacting with people, automated reactions almost always mean that we are stereotyping and not examining the ways in which a situation differs from previous ones. Conway and Kane (2005) explained this well, writing that "the solution to life's problems often requires that such automatically elicited thoughts, associations, and captured attention be resisted and thought be directed or controlled" (p.777). Mindfulness, which will be discussed in Chapter 4, allows people to practice and get into the habit of actually consciously experiencing tasks that have been automated.

We will never be able to compare the outcomes in an automated process with our goals, but not all components of a multitasking event require such a comparison. Therefore, in a multitasking situation, we might consciously consider which aspects can be automated and which should be kept in working memory. For instance, in writing an essay, we clearly would want the physical act of typing to be automated, and perhaps sentence structure or paragraph organization, but the content should be kept in controlled processing.

As evidenced here, automaticity is one way in which multitasking ability can increase. However, automating particular processes may be at the expense of explicit memory, and by extension learning, in which case the automation and subsequent ability to multitask might be detrimental (Judd & Kennedy, 2011). The compelling part of this research is that those with higher WMC actually use more controlled processes in decision making. Conversely we see that automaticity is essential for increasing performance on complex tasks. This is why a conscious decision making process is necessary to move something from controlled to automatic in a thoughtful way, in a way that allows certain important processes to be maintained in conscious awareness and disallows negative stereotypes.

## Chapter 3: Self-Regulation and Goal-setting

All task performance, including juggling several tasks at once, requires self-regulation. Self-regulation can be broken into three components: goal-setting, development of strategies for achieving the goals, and metacognitive awareness that monitors the progress toward those goals. Self-observation serves at least two of these functions in the process of self-regulation. It provides the information needed for setting realistic goals and for evaluating one's progress toward them (Bandura, 1991). When people monitor their performance they set goals of progressive improvement, even when there is no external directive. This chapter aims to examine the ways in which self-regulation, goal setting and goal monitoring in particular, facilitates successful balancing and completion of several tasks.

*Self-regulation* is a complex term, which has been argued not to be complete with the three components listed above. Zimmerman (1995) argued that self-regulation also necessitates a degree of self-efficacy and personal agency, as well as the motivational components of those constructs. That self-regulation could improve with scaffolding around goal setting and metacognition alone would undermine the Social Cognitive Theory (SCT) of self-regulation that was proposed by Bandura (1991). The self-efficacy component of SCT can be defined as a person's belief about their ability to exercise control over the way they function. Self-efficacy both precedes and follows goal setting. For instance, the choices we make and the goals we set are based on this belief about oneself, and the way in which we follow through on the goals we set is also determined significantly by this self-perception (Bandura, 1991). Much research has been done on processes for increasing an individual's levels of self-efficacy, and like all productive task completion, it is essential for multitasking. However, aspects of self-regulation that involve goals and goal monitoring are more central to the discussion.

Bandura (1991) argued that intention and desire alone cannot impact behavior significantly if a person lacks “capability for exercising influence over their own motivation” (p. 249). One aspect of self-regulation, which underlies that ability, is self-monitoring, or paying attention to one’s performance, the conditions under which it occurs, and the effects that are produced. Another aspect is self-diagnosis in which people recognize patterns in their behavior and adjust that behavior accordingly better to achieve goals. The last aspect is the self-motivating function of self-regulation in which people set goals for “progressive improvement” based on evaluation of performance throughout task activity. These pieces work in tandem to determine the progress one makes in addressing singular and multiple goals.

**Goal setting theory**

According to goal-setting theory, the core properties of an effective goal are its specificity, its difficulty, its effects on the self and the group, its balance of learning versus performance goals, the effect of the goal source, and the role of incentives (Locke & Latham, 2002). There is much to consider when effectively setting goals. In multitasking, the success of goals is even more complex as several competing goals interact.

Task complexity is a moderator of goal setting discussed by Locke and Latham (2002). They wrote that the effect size for goal setting is small when task difficulty is high. The effect size, although smaller than with less complex tasks, is still significant. However, with complex tasks, task strategy is most correlated with task performance.

They also wrote that proximal goals facilitate performance most in complex tasks and that those proximal goals may be effective due to their role in error management, which is related to task monitoring.  Additionally, there is empirical support for the notion that setting high performance goals actually increases intrinsic motivation (Locke & Latham, 2002). Presumably, increased intrinsic motivation seems to lead to more goal-commitment and prolonged attention.

Intuitively it may seem that self-set goals would have a more significant impact on performance than goals set by others. However, those self-set goals must be appropriately difficult to have that impact. Participants in a self-set goal condition performed fewer task-switches but had lower overall performance when compared to participants in a no goal condition. Strickland and Galimba (2001) found that the goals set by participants in the goal-setting group were actually lower than the scores they had gotten on the pre-experimental test. This result should not lead to the conclusion that goals impede performance, but that goals actually significantly affect the way people perform. If a goal is set lower than the performance level prior to setting goals, than goals can actually have the opposite regulatory effect, and a person may diminish effort in order to reach the lower set goal.

Strickland and Galimba (2001) did find results that indicated that self-set goals structured participants' work patterns, with "less switching between tasks relative to the work pattern of a group of participants who did not set goals" (p. 357). Again, task switching does have an assumed cost. Multitasking is not "best" when task-switching is least, as evidenced by the results from a study that found an optimal arousal level dependent on task difficulty (Adler & Benbunan-Fich, 2011). However, each task switch has a cognitive cost with the goal of the left task needing to be continually rehearsed in order to more quickly reorient to the task. Goals left unrehearsed during an interruption will decay, resulting in longer resumption times (Ridley, Schutz, Glanz, Weinstein, 1992). Therefore, when unnecessary task switching is reduced due to effective goal setting and goal monitoring, productivity is highest.

**Practical goal setting**

One way of setting goals that are more nuanced and specific is mental contrasting. *Mental contrasting* is the process of imagining a desired future and then examining which components of the present impede the achievement of that desire (Oettingen, Kappes, Guttenberg, & Gollwitzer, 2015). Oettingen & Kappes (2015) wrote that "mental contrasting with high expectations strengthens the implicit associations between the desired future and the present reality" (p. 219). With mental contrasting, people become energized to overcome the present obstacles to their desired future. Mental contrasting is considered a metacognitive strategy for achieving better planning and monitoring skills. Oettingen used the theoretical support of mental contrasting to test its efficacy in producing better time management in pursuit of goals. In her study, she found those who were taught the skill improved their time management. In fact she found that students who held high expectations, due to mental contrasting, initiated immediate action toward their goal, whereas those with low expectations delayed their actions.

The relationship between delayed action and self-regulation again brings in the concept of procrastination, which was mentioned in Chapter 1. Procrastination and multitasking are convoluted, intertwined terms. If successful goal setting and subsequent task completion involves the self-regulation skills of planning and monitoring, then procrastination multitasking can be seen as the maladaptive version of successful task-switching. Additionally, planning has been considered an apt remedy for overcoming procrastination. Planning involves setting goals, subgoals, and time structures, and these combined can lead to successful task achievement rather than procrastination (Van Eerde, 2000). This idea further puts procrastination and successful mutltitasking at opposite ends of a spectrum when evaluating productivity and achievement of goals.

Task switching is the moment when attention breaks, and an alert about a competing goal arises. This can either be adaptive or maladaptive depending on the circumstance. If the switch is to divert attention from a more important task to a less important task, for instance, from focusing on an important assignment to looking at photos, then it would be maladaptive and detract from overall goal management. However, if the switch is to change attention to a competing goal that has a stronger time urgency than the current task, for instance, if you were to remember to take your dinner out of the oven in the middle of that assignment, such a switch would be adaptive. What differentiates a person whose task switches are typically effective and vital and a person whose task switches are preventing her from accomplishing what she truly wants? Aimless task switching arises from less planned complex tasks. As evidenced by the fact that people who are equipped with goal setting and goal monitoring are less likely to task switch unnecessarily, initial goal setting and subsequent shifts to adapt to the progress toward goal are vital for multitasking success.

Ridley & Schutz (1992) looked at self-regulation in terms of two processes: goal setting and metacognitive awareness. Their experimental design and its outcome underscore a fascinating aspect of success in decision-making tasks that I argue are also imperative to successful multitasking. In their study, they measured individual differences in metacognitive awareness and then placed participants in either a goal-setting intervention or control group. Results showed that those participants who were asked to define goals clearly and who also had a high degree of metacognitive awareness performed best in novel decision-making tasks. In the decision-making task, participants were asked to keep track of four pieces of onscreen information and make complex decisions. Although this was not designed specifically to examine multitasking, it could be considered a multitasking event.

Goal setting is not successful without the metacognitive awareness necessary to remind people of the goal at certain intervals. This awareness can go from nonexistent, to adaptive, to interfering. Metacognition that interferes demonstrates the way in which it can contribute to cognitive load. (Scott & Schwartz, 2007) Here is an example of how an excess of metacognition can actually get in the way of task execution. In their study, Scott & Schwartz (2007) found that students already high in metacognitive skills who had the strategies in place to question material deeply actually suffered in terms of performance from scaffolded metacognitive aids to processing content information. When considering the ways in which increasing self-monitoring helps in the achievement of goals via on the spot adjustments to one's plan, it is necessary to acknowledge that certain types of scaffolding might actually be a detriment to performance if it is redundant with pre-existing self-monitoring skills. For this reason, improving a person's multitasking strategies must be done via an individualized approach.

Developed by Shallice and Burgess (1991), the Six Elements Test (SET) is used to measure a person's ability to achieve a goal that involves balancing several tasks, with time constraints and task rules. Participants must follow particular rules regarding which tasks can be performed when, self-monitor their progress, and manage these tasks with limited time. This test for multitasking has been used to look at variations in deficits for frontal lobe injured individuals.

One disorder for which using the SET becomes an interesting tool is what is referred to as strategy application disorder (SAD). SAD presents itself as a difficulty performing complex problems that involve goal-related behavior. Burgess (2000) looked at multitasking as a prototypical situation that would prove difficult for someone with SAD. Interestingly, people with SAD exhibit unimpaired IQ, memory, language, visuo-perceptual functions, and even perform normally on a number of executive functioning tests. Instead, individuals with SAD have lost the ability to function specifically in areas that are vital for multitasking.

Failures on the SET could not be explained by low motivation. Instead, Burgess et al found the work rates to be the same between the IQ matched controls and the subjects with SAD. The authors attributed poor performance on the SET to issues with the component of multitasking of delayed intentions. They described delayed intention as requiring prospective memory, or the creation and realization of intentions. This description is similar to the self-regulation strategies laid out in this chapter of goal setting and monitoring. This relatedness again underscores the necessity of these self-regulation skills in successful multitasking.

Burgess, Veitch, de Lacy Costello, & Shallice (2000) wrote about the three constructs they theorized enable high performance on the SET. They included retrospective memory, which is very similar to the definition of working memory capacity from the previous chapter. Secondly, they wrote about planning which is essentially the initially goal setting component of a task. Lastly, they explained intentionality, which is a construct that represents the ability to follow a self-created plan and follow task rules. These three constructs together allow for someone to manage multiple goals and switch between tasks.

Another group of individuals who have shown difficulty on the Six Elements Test are those with ADHD. Siklos and Kerns (2004) proposed that impairment to the Supervisory Attentional System, which controls "goal-directed behaviors in novel situations, such as goal articulation, plan formulation, decision-making, marker creation, and marker triggering" (p. 348) could be a characteristic of individuals with ADHD. They went on to claim that most tests of executive functioning fail to examine this goal articulation component because the goal of the task is explicitly laid out. The SET, however, pinpoints planning, organizing, and monitoring in a specific way. The results of their use of a modified SET with children with ADHD showed evidence that those individuals were not different in their ability to remember the task rules; rather, children with ADHD appeared to have a specific deficit in monitoring their ongoing behaviors and generating useful strategies for task completion, as indicated by the decreased number of tasks attempted compared to the control group.

Considering that SET performance requires remembering task rules, using working member capacity, and requires planning and monitoring progress toward goals, or self-regulation, we need to examine ways of improving those skills. One example of helpful scaffolding is simply encouraging individuals to set goals when confronted with any task. Goals that exceed previous performance or even expected performance can increase intrinsic motivation. Time attitude and short-range planning, as discussed in Chapter 1, have been shown to increase performance in longer term complex tasks (Britton & Tesser, 1991). Monitoring goals in a shorter time frame also involves planning with time awareness strategies and deadlines.

Time awareness underlies the reminders that people give themselves to switch from one task to the next. Separate from the ring of a phone or an interruption by a knock, self-interruptions come about due to time awareness. In their unified theory of multitasking, Salvucci, Taatgen, and Borst (2009) proposed a computational model of psychological time to explain the way in which people estimate the amount of time spent on a task. Then, with the monitoring of time in place, a person can decide to switch tasks at a particular time interval, if a plan has been made or if progress toward goals is being monitored.

Salvucci and Taatgen's (2008) threaded cognition theory posits that cognition maintains a set of active goals in a multitasking event. In order to allocate resources to those separate goals, maintenance and monitoring of goals as they progress is a necessity. When we maintain awareness of goals, we can track progress toward them and make adjustments when needed. When goals are set and subsequently abandoned, they have no function in affecting performance. Our ability to monitor goals, track the passing of time, and adjust behavior when circumstances change or a plan does not unfold in an expected way are some of the primary bases for successful multitasking.

# Chapter 4: Mindfulness and Time Awareness

This chapter will outline the ways in which mindfulness and time awareness can influence multitasking performance. With consideration of cognitive load theory and goal setting theory, outlined in the previous chapters, mindfulness and time-awareness are two concepts that may work with these theories to improve task switching so that it is effective and works well with the goals an individual has set.

Mindfulness is a conscious and regular drawing of attention back to the present moment. Davis and Hayes (2011) defined mindfulness as “moment-to-moment awareness of one’s experience without judgment” (p. 198). In their review article, they wrote that multitasking has been demonstrated to promote metacognitive awareness, increase working memory, and enhance cognitive flexibility. These constructs are related to multitasking performance, and therefore it would follow that mindfulness-based interventions could show improvement to multitasking.

Ie, Haller, Langer, & Courvoisier (2012) found that training in multitasking in the short term produced no differences in multitasking performance. However, they did find that trait mindfulness predicted multitasking performance in the no treatment control group. These findings mean that a state-based mindfulness intervention did not have a significant enough impact on the aspects of mindfulness to result in better multitasking., but that the more long-term effects that come from trait mindfulness could.

In a chapter entitled “The Role of Intention in Self-Regulation,” Shapiro and Schwartz (2010) wrote that connections between parts of a whole “enable the parts to affect each other’s behavior, but, more importantly, allow the system to control the global operation” (p. 255). They claimed that this interactive organizational process is a way of conceptualizing self-regulation. Importantly, in systems theory, systems are understood both as the connections between components as well as governance of the entire system as a whole. Thus, the systems level thinking needed for multitasking comes not from random interrelating of concepts but from the global operation of control and awareness present in a mindful state.

Shapiro and Schwartz (2010) argued that self-regulation involves “attending” to whatever may be the subject of the sustained focused awareness. The authors cited studies that have demonstrated that focused attention on one’s breathing leads to deeper, more regular breathing. In focusing attention, deeper noticing takes place and the complexity with which we can understand increases. Shapiro and Schwartz (2010) also write that “self regulation is the process through which a system maintains stability of functioning as well as flexibility and the capacity for change in novel situations” (p. 259). Most important to its relationship with mindfulness is that self-regulation begins with intention rather than simply attention. This distinction is invaluable in differentiating mindfulness from other states of mind, and gets more clearly at why it is so essential for multitasking: the presence of intention, or goals, means that there will continue to be a conscious pruning process, through self-monitoring as thoughts arise that will both prevent distractions and increase examination of related ideas.

Levy, Wobbrock, Kaszniak, & Ostergrn (2012) compared multitasking behavior among participants in a control group, participants who did an eight-week mindfulness meditation course, and those who did an eight-week body relaxation course. The authors found that only those in the mindfulness meditation group made fewer task switches and stayed on tasks longer. The authors did not look at multitasking performance, however, which has been shown to vary in terms of what constitutes better performance. They did find that those in both the body relaxation and the mindfulness meditation courses had greater increases in memory for discrete information than those in the control group. This finding could be related to similar increases in multitasking performance when performance is based on accuracy. Additionally, the findings may contrast with Ie et al (2012) because Ie et al were looking at performance and not behavior, or because Levy et al (2012) used an eight-week course as compared to a short thirty minute training.

**Working Memory Capacity**

Chiesa, Calati, & Serretti (2011) aggregated 23 studies that examined attention and memory. They found that mindfulness training improved working memory and executive functions. Mindfulness has a definitive relationship with the controlling of attention that constitutes WM in that its practice was shown to improve cognitive inhibition, specifically in terms of stimulus selection (Bishop, Lau, & Shapiro, 2004).

Mrazek, Franklin, Phillips, Baird, & Schooler (2013) found that a two-week mindfulness training improved both GRE scores and working memory capacity while simultaneously reducing the prevalence of distracting thoughts. This improvement demonstrates the way in which mindfulness may provide the metacognitive monitoring strategy to discriminate between pieces of information that are distracting and pieces of information that are necessary for successful task completion.

Jha, Stanley, Kiyonaga, Wong, & Gelfand (2010) looked at the protective effects of mindfulness training on working memory capacity and affective experience in military cohorts. They found that the intense demands of pre-deployment training decreased WMC, but that soldiers in the high practice mindfulness training group showed modest improvements to WMC. If mindfulness has a distinct positive effect on working memory capacity, then it may say something about the relationship between mindfulness and multitasking. As they claimed, mindfulness may act as a remedy for "high-stress intervals" with "deleterious effects" on WMC. The effects of pre-deployment may be attributable to significant levels of high-pressure multitasking. Therefore, the positive effects on mitigating that degradation to WM may be transferable to some of the same performance deficits that come from high levels of multitasking I discussed in Chapter 1. (Ophir et al, 2009; Carrier et al, 2014)

**Heuristic Thinking and Cognitive Flexibility**

Moore and Malinowski (2008) explored the link between meditation, self-reported mindfulness, and cognitive flexibility. Their results demonstrated that meditation and levels of mindfulness have a significant positive effect on cognitive flexibility. Meditators had higher self-reported mindfulness as well as more positive effects on measures of attention. Although Moore and Malinowski focused on how attentional control and cognitive flexibility promoted well-being, these two aspects may be related additionally to multitasking ability. If mindfulness can be cultivated through attentional exercises and meditation, it would follow that those effects of increased attention and mental dexterity could be useful for task switching.

In an article on the neural integration of mindfulness, Seigel (2007) writes, "when we achieve new skills of self-observation through mindful practice, it becomes possible to disengage automatically coupled pathways" (p. 260). Getting at the heart of how mindfulness training enables increased awareness of one's thoughts, thereby clarifying the process by which one connects concepts, and putting the power to be creative and flexible rather than engaging in mindless meanderings. Moments of striking awareness allow individuals to avoid the distraction of subjective associations, and to assess pieces of information for relevance. Mindfulness practice supports and increases the prevalence of this state of mind. It would seem reasonable that mindfulness practice should be considered an invaluable component of cultivating problem solving oriented minds.

Quinnell, Thompson, and LeBard (2013) wrote about the relationship of mindfulness and a person's readiness to "cross liminal space" or move through the process of knowing something as a novice to understanding it as an expert. Mindfulness contrasts strongly with rigidity of mind, and therefore opens a person up to exploring relationships between concepts and away from prohibitive statements like "I'm not a math learner." Quinnell et al also stated that success in math does not come from being able to perform calculations but knowing when and how to apply those math skills. They went on to say that tackling the "rigidity of mind remains our biggest challenge" (p. 812). The focus on creative problem solving and higher order thinking associated with a mindful mindset may be the solution to a block in math learning, and similarly to the challenges one confronts in a multitasking scenario. Another way of understanding this is mindfulness as a precursor to heuristic thinking strategies. If heuristic thinking provides a generally faster solution to a problem, because a person avoids the step-by-step dependence on rules, then increasing automation helps alleviate the cognitive load of strategy awareness and increases the space available for controlled processes.

Although their study found no significant effect of training, Ie et al (2012) found that a trait-based heuristic mindset did correlate with higher multitasking performance. Heuristic thinking contrasts with algorithmic thinking in that algorithmic thinkers prefer to approach problems using a defined set of strategies and tackle new problems with familiar tactics whereas heuristic thinkers prefer shortcuts, estimates, and novel approaches. Further, people engaged in convergent thinking, aligned with low heuristic thinking, have displayed increased task-set shielding of the primary task which comes at the cost of reduced cognitive flexibility for multitasking (Fischer & Hommel, 2012). The fact that *heuristic* may be another word for the automatic processing described in Chapter 2 gets at why this way of thinking correlates with multitasking performance. Heuristic thinkers are flexible enough in their thinking to reuse schemas from other tasks and manipulate them appropriately to reduce conscious processing.

Thus, on one hand, blocking out distractions is a self-regulatory strategy that has positive effects on working memory capacity and thus multitasking ability. In contrast heuristic thinking is not focus or attention, but rather heuristic thinking is an opening up to possibilities and connections in order to solve problems with flexibility rather than through an algorithm (Haller & Courvoisier, 2010). To be clear, the type of opening up to possibilities that mindfulness enables is not distraction. Distraction, which comes from external sources or internal mind wandering, disenables powerful multitasking by depleting working memory. The opposite is true of heuristic thinking which, due to this increased awareness around the task at hand, allows a person to connect existing methods for problem solving and existing thoughts around a subject to be brought to the forefront of the conscious mind.

Relevant again is Adler and Benbunan-Fich (2012) who wrote that "individuals had the highest creativity when they had the discretion to switch tasks, and each task had a specific goal" (p. 158). Here is the intersection and symbiosis of creative thinking, often measured by heuristic thinking and task switching. Mindfulness and effective task switching can work in tandem to increase a state of mind that blocks out unrelated concepts and interconnects tasks using schemas and conscious thought.

Heuristic strategies are often used to teach expert problem solving, but have been said to be less effective without metacognitive strategies (De Corte, Verschaffel, & Eynde, 2000). This also points to the reasoning that goal setting and attention are the necessary structure within which we multitask. A person high in heuristic thinking and low on self-regulation and goal setting might flit from task to task too rapidly or engage with a task without full attention. A person with high levels of self-regulation and goal setting on the other hand might be excellent at monotasking but have difficulty integrating the concepts or complex multitasking events due to algorithmic thinking, which prescribes linear completion of tasks rather than an interleaved approach to multiple tasks. A person who has both high heuristic thinking and self-regulation may demonstrate the right combination of skills to effectively multitask.

Taken together, the effects of mindfulness on a person's state of mind are impressive. The induction of mindfulness over time may positively impact the components necessary for effective task switching behavior: cognitive flexibility, self-regulation, and working memory capacity

**Time Awareness and Task-Switching**

How we recognize the passage of time may be the basis of time perspective theory. This paper has focused primarily on the aspect of multitasking that involves the focused attention of a singular cognitive load. However, the ability to recognize when it is time to switch tasks is also a vital component of the process. The notifications of urgency to switch tasks propel us forward toward task switching in a multitasking event.

Because what differentiates tasks is that they have different goals, not that they require different modalities, the infiltration of the need to address a goal would be what causes a task switch. But what determines when and how often those notifications come up? The frequency can become maladaptive and obsessive if it causes a person not to have the focus to complete a singular cognitive task because they are so distracted by the notifications.

The concept of time perspective (TP) stems from the way in which humans are aware of passing time and try to make sense of it. Zimbardo and Boyd (1999) defined TP as "a nonconscious process whereby the continual flow of personal and social experiences are assigned to temporal categories, or time frames, that help to give order, coherence and meaning to those events" (p. 27). Time perspective can vary from past to present to future orientations and Zimbardo and Boyd point out that it is adaptive to take on all of these orientations for different events. Different time perspectives influence the way in which people act and make choices.

The “temporal distance” of a task affects a person’s ability to classify its importance and relevance. If a person attributes a particular temporal urgency to certain tasks, it may be considered an aspect of the goal they set (Stanescu & Iorga, 2015). Clearly, temporal consciousness would therefore play an important role in how the person would organize, plan, and execute multitasking events.

Stanescu and Iorga (2015) proposed that a future time perspective orientation can actually increase the “individual amount of motivation and effort-expenditure” (p. 12).

Demeyer and De Raedt (2014) found that a person's time perspective had a significant effect on the way in which attention was biased, either toward positive or negative information, or both. Further, de Bilde, Vansteenkiste, & Lens (2011) found that future time perspective actually regulated student study behavior through feelings of guilt and shame (introjected regulation), personal conviction (identified regulation), and interest (intrinsic motivation). Moreover, the authors found that a present fatalistic and present hedonic time orientation related to "more negative motivational and learning correlates" (p. 332).

Although these studies relate time perspective theory moreso to general avoidance or engagement rather than to specific multitasking events, from their results it can be hypothesized that having a future time perspective may be related to the concept of polychronicity, which does not correlate directly with multitasking ability. This line of thinking stems from the fact that people oriented to the future have a sense of urgency around task completion that may encourage more multitasking behavior. I have made the case that more multitasking does not mean better multitasking. A future time perspective that would lead to unnecessary task switching would most certainly mean worse multitasking outcomes. However, a future time perspective over the long term, balanced with present time perspective over the short term, could create the working balance of urgency and focus needed for effective multitasking.

Time motivates us forward, but stress around time can make attention to the present moment difficult. That stress burdens cognitive load and leaves problem solvers more distracted than engaged. Research around time perspective theory and task switching would give another way to approach workable scaffolds for teaching students to juggle many activities and classes as well as to help adults manage their complex lives.

## Conclusion

In this paper I have laid out ways in which multitasking has been defined, and the component pieces of the process that can be improved via changes to self-regulation, working memory, and heuristic thinking. I acknowledge that monotasking nearly universally leads to better accuracy, but that the Yerkes-Dodson law can predict optimal rates of task-switching for productivity.

In the second chapter, I presented evidence for the conclusions that higher WMC leads to more actions fitting into a singular attention span, but that the majority of WMC improvements found experimentally come from relegating component pieces of a process to automation. Increased automaticity leaves space in working memory for more complex processes.

In the third chapter, I looked at changes to self-regulation through goal setting and goal monitoring as ways to lower the cognitive load required for maintaining multiple foci. Such reduction happens via conscious pruning of unwanted information and active reorientation toward goals.

In the final chapter, I looked at time awareness perspective as an individual difference variable worth considering for its effects on urgency of task switching. Further, I examined the effects of mindfulness training on improving self-regulation, working memory, and heuristic thinking through avoiding urges to engage with distracting information and remaining more deeply focused on a given task.

There are many areas for future research including additional empirical testing of the ways in which mindfulness-based interventions could impact multitasking specifically. Still, clarity around conscious, effective multitasking must be found.

Multitasking has been conflated with procrastination and distraction, but is simply a label put to the way our minds run at all times and learn to automate tasks. In the same way that we are learning animals, we are multitasking animals who can take once complex activities, like driving or playing piano, and do them without conscious thought. This ability encourages multitasking. Acknowledgement of that tendency can help us to bring certain tasks back into conscious awareness, like being present in a meeting or working on an assignment. Multitasking, when it leads to mindless choices in important decisions or when it leads to induction of stereotyping to the detriment of what one would consciously want, should be avoided. This is why further research and development of the concept of mindful and effective multitasking should take place. Additionally, it is only with an end goal in mind that we can approach making decisions about automatic versus controlled processing, and which would be better for a given task. Therefore, we must think about end goals when determining methods for undertaking tasks.

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