Overview: The Science of Mental Bandwidth

Tina D. Bhargava, Kent State University

Introduction

What might stop someone from making choices that serve them well? Is impulse control primarily an issue of "self-control" or "willpower"? Are some behaviors harder to change than others? In general, people don't really factor in the important impact of cognitive factors on human behaviors. A better understanding and acceptance of these factors can lead to better strategies for shaping behaviors and more opportunity for success.

Researchers in the fields of applied psychology and neuropsychology (and many other related fields...) study how cognitive factors affect task performance. In other words, what kinds of cognitive demands do certain tasks require and what determines whether people have the cognitive capacity and motivation to complete those tasks? It is important to recognize how complex and cognitively demanding some behaviors may be. Asking individuals to engage in new behaviors or change old behaviors have unreasonable cognitive demands, but that aspect is seldom explored. Are our expectations of our own and others' behavior cognitively reasonable and do we understand how demanding certain tasks can be?

The following review explores several important cognitive factors that affect task performance and that are commonly studied in applied psychology. These factors center around the concept of attentional resource capacity ("mental bandwidth"), and include task demands, skill acquisition, cognitive interference, and self-management.

Attention and Attentional Resource Capacity ("Mental Bandwidth")

The concepts of attention and attentional resources have been studied extensively. They are important to consider when analyzing task performance because they help explain the cognitive processes—and limitations—of an individual. Three underlying conceptualizations of attention serve as the basis for much of the literature (Parasuraman & Davies, 1984).

First, attention can be viewed as a mechanism for separating information into things that are noticed and things that are not noticed. In other words, attention refers to analyzing how and why some information is perceived by an individual, while other information is ignored. Research in this area of attention tends to focus on this selective process and the factors that influence it. In other words, why do we pay attention to some things and not others?

Second, attention can be viewed as an information processing resource. It is widely accepted in the field that individuals possess a fixed amount of attentional resources (Kahneman, 1973). As a simplified example of attentional capacity, assume that an individual has 100 units of attentional resources per second to process information. If the individual is given two tasks to complete in one second that each require 75 units of attention, there are many possibilities for how these attentional resources might be allocated.

For example, the individual may do the tasks consecutively, which means one task would be completed (using 75 units of attention), whereas the other would be only partially completed (25 out of 75 of the units of attention needed would be allocated). Or the individual may attempt to do the tasks simultaneously, which would necessitate that the individual switch attentional resources back and forth between the tasks, leading to only partial completion of one or both tasks. In either scenario, combining tasks in which attentional capacity is exceeded (150 units required when only 100 are available) is likely to result in reduced or incomplete task performance (Schneider et al. 1984). The key question here is: how much attention do we give to certain things?

Finally, attention is discussed in terms of types of information processing. This area of study focuses around the theory that there are two qualitatively different processes of human performance (Chaiken & Trope, 1999; Schneider et al., 1984). One type of processing is a fast and fairly effortless process, which is often referred to as "automatic." Automatic processing is generally not under direct control of the individual. In other words, we are seldom conscious

Address correspondence to Tina D Bhargava, Kent State University, 313 Lowry Hall, Kent, OH 44240; tbharga1@kent.edu.

of the automatic information processing that takes place.

The other type of processing is characterized as slow, effortful, regulated processing, and is sometimes referred to as "control." Control processing is typically used to deal with novel tasks or information. While the distinction between automatic and control processing is an important one, it is also necessary to note that, most likely, all tasks are carried out with some mixture of automatic and control processing (Schneider et al. 1984). Here we ask: how much attentional capacity do we have?

There are several important points that can be made when taking into account both the limited capacity of attention and the types of information processing. Control processing uses most of an individual's attentional resource capacity. On the other hand, automatic processing tasks use very little attentional capacity. Therefore, several automatic processing tasks can be completed successfully even when they are conducted simultaneously and without full awareness of the individual.

In contrast, control processing tasks must compete for attentional resources in order for a task to be completed successfully, and individuals are generally well aware of the completion of these tasks. The part of our brains that governs conscious awareness and control processing is estimated to be able to process about 60 bits per second, which is roughly equivalent to a short sentence. Yet the overall processing capacity of brain is estimated to be 11 million bits per second, indicating that the vast majority of tasks are carried out automatically (Cohen, 2008; Dijksterhuis et al., 2005).

It is interesting to note that people will have more difficulty controlling and modifying their processing for automatic tasks than for control tasks (Schneider et al. 1984). Individuals usually do not find it difficult to focus on control processing tasks. However, as performance becomes more automatic, people have more difficulty controlling and modifying their processing.

For example, automatic processing is generally used when chewing and swallowing food. However, if an individual were asked to make sure that each bite of food was chewed 25 times, then the process of chewing would switch to a control processing task. The individual would have focus on the chewing as well as the counting, and would likely be highly susceptible to distractions, which would cause the individual to revert the chewing back to automatic processing. Focusing on and changing automatic processes is actually quite difficult and consumes attentional resources. Some studies have shown that counter-acting automatic processing requires more attentional resources than normal control processing (Schneider et al. 1984).

The Stroop test is sometimes used to measure attentional resources or attentional fatigue. The test relies on the common ability of people to automatically identify simple, written words. In the test, names of colors are displayed in a different color from the color named. For example, the word "red" may be displayed in blue. Identifying the word "red" is a faster and more automatic task than identifying the color blue. Therefore, when shown the word and asked what color it is, an individual has to use control processing to focus on the color of the word rather than the word displayed. Individuals with higher levels of attentional resources and less attentional fatigue will complete this task more successfully (quickly). (De Young, n.d.)

Task Demands

Effectiveness at performing a task is also dependent on the demands of that task. Task demands are described in terms of two factors: task difficulty and task consistency.

Task difficulty consists of the amount of knowledge that must be learned (Anderson, 1993) and the number of problems that must be solved (Newell, 1990) to perform the task (Steele-Johnson et al., 2000). Paas and Van Merrienboer's (1994) description of "mental load" in terms of the number and nature of component skills involved in task performance is consistent with this definition, as is Wood's model of task complexity (Wood, 1986). For example, an individual may be asked to arrange 100 students into 5 different classrooms. A task with lower difficulty may give the individual only one rule to follow in performing this task (e.g. each classroom must have an equal proportion of male and female students). A task with higher difficulty would have several more rules, which may involve incorporating students' schedules when making classroom assignments, and ensuring that students of varied IQ levels are evenly distributed among the classrooms.

Task consistency involves the level and type of information processing demands. Robert Wood proposed the concept of "component redundancy," which refers to the degree of overlap among the task demands (Wood, 1986). A high level of component redundancy leads to a generally consistent task, i.e. the individual completes the same task over and over again. An inconsistent task is one in which the task demands are changing. For example, if an individual was asked to complete the classroom assignment activity described above three times in a row, each time with a different set of rules, this would comprise an inconsistent task. Completing the activity three times in a row with the same rules and parameters would be a consistent task.

Task difficulty and consistency can affect the "cognitive load," or amount of attentional resources required for a task (Steele-Johnson et al., 2000). Task consistency, in particular, has been shown to be an important factor in whether a task requires control processing or automatic processing. Several studies have demonstrated that the performance of tasks with consistent information-processing demands can be automatized with task practice, thereby freeing attentional resources (Schneider et al, 1984; Schneider & Shiffrin 1977; Shiffrin & Schneider, 1977).

Reading is a good example of a consistent task that can be automatized with practice. When someone first learns to read, control processing is used to deal with the novel information that is presented. As the task of reading is practiced, many of the elements of the task become automatized—the person no longer uses control processing to recognize each letter or to put it into context with the other letters. Because the "rules" that govern reading are generally consistent, the individual is able to practice the task and automatize the processing of the information provided. This frees attentional resources for control processing that allow for understanding and interpretation of the text. The process of automatizing a task is described further below, in the discussion of skill acquisition.

Tasks with inconsistent information-processing demands require continued high levels of attention to successfully perform the task. Because the task demands are changing, the individual cannot automate the process. For example, imagine that an individual purchased a desk, a dresser and a bookshelf from three different manufacturers that all needed to be assembled. For each piece of furniture there is a different set of directions. Following the directions for assembling any of the pieces of furniture takes control processing, as each step requires high levels of attention to the directions. And assembling the desk is unlikely to make assembling the bookshelf any easier, since each process has its own set of directions written by different manufacturers. Assembling these pieces of furniture is an example of an inconsistent task. For inconsistent and novel tasks that require control processing, attentional resources must be allocated among competing tasks.

Task difficulty may also affect whether automatic or control processing takes place. Novel tasks, whether difficult or not, typically require control processing. Although it may seem as though more difficult tasks would require control processing, this has not always been shown to be the case. Automatic processing may not seem possible for the entirety of a difficult task, but it may well be adequate for the consistent aspects of the task. Automatic processes can allow people to perform very complex tasks that are a compilation of smaller, automatic tasks. The example of reading, which is a difficult task, demonstrates that automatic processing can be sufficient for completing many facets of difficult tasks.

Skill Acquisition

Research on the acquisition of cognitive skill has received a great deal of attention (Anderson, 1982; Fitts, 1964; Fitts & Posner, 1967; Fu, 2008). Skill acquisition is an important aspect of task performance and is often discussed in terms of two components: practice and the development of task strategies. Practice is typically used to shift a new task from control processing to automatic processing, allowing more attentional resources to be available to the individual. The development of task strategies aids in the overall development of schemas.

A schema is defined as a highly integrated representation of complex skills. In lay terms, a schema might be considered a very specific set of instructions about how to do something. As an individual works through a task, he or she makes determinations about how to do each step. With a consistent task, an individual has more opportunity to refine this schema each time the task is performed, with the eventual goal of developing a schema that can be automatized.

Consider the example of preparing to go outdoors in the winter. The first time one does this, one might first put on gloves, then a coat, then boots, then a scarf, and then a hat. After this task is completed, one might realize that it is easier to put the gloves on after the coat is zipped, and that the scarf is more effective when worn under the coat. The next time this task was presented, one might follow these new guidelines.

Repeated experiences would likely lead to refinements in the "winter wear" schema. After repeating this task several times, a preferred schema might be developed that is acceptable for all future uses. Once the task has been presented several more times and the preferred schema has been used consistently on these occasions, then the task can begin to become automatized. In other words, the person prepares their winter wear without thought, potentially while carrying on other tasks.

Skill acquisition and the use of practice and task strategies are affected by the difficulty and consistency of the given task. For more difficult tasks a larger number of task strategies must be learned before an individual can perform the task effectively. In these cases, skill does not develop from practicing the skill, but rather from practicing and automatizing the consistent components of that skill. For an inconsistent task, effective task strategies might change with task changes. Therefore, practicing the task procedures will have little effect on performance. The processing for inconsistent tasks is unlikely to become automatic, regardless of amount of practice.

With the "winter wear" example, consider the consequences if the weather was unpredictably and qualitatively different every day. One day might require a coat and boots and the next would require flip-flops and a sunhat. Each different weather scenario is a new, inconsistent task, and there is limited opportunity to develop or refine a schema.

Cognitive Interference and Ability

Human thought shifts focus at a high rate. Cognitive interference is a term to describe off-task thoughts that affect task performance (Sarason et al., 1996). Using attentional resources for off-task thoughts—i.e. worrying about what someone else is thinking about you instead of attending to the task—may take away from task performance. Others set forth that some types of cognitive interference may be useful or enhance task performance (Miller, 1996). While the presence of both the thoughts and the interference are considered normal mechanisms of human thought (Klinger, 1996) it is important to consider their influence on task performance as described above. Some forms of cognitive interference may be preventable or controllable, which may lead to overall improvement in task performance.

There are many potential sources of cognitive interference. Some of these sources are often considered to be specific to each individual's traits, such as tendency towards anxiety or depression, or ability to cope (Yee and Vaughn, 1996). For instance, multiple studies have demonstrated that anxiety can lead to task performance deficits, likely due to the focus on intrusive threat-related thoughts that occur frequently in anxious individuals (MacLeod, 1996).

Depressed persons report particular difficulty with cognitive functioning, such as poor concentration, forgetfulness, and intrusive negative thoughts (Gotlib et al. in 1996). However, the presence and severity of cognitive deficits in depression seems to depend on the situation and type of task. Stress may also lead to cognitive interference. This often depends on whether the stress is self-imposed (a challenge to oneself to do better) or externally imposed (a demand to do better), with externally imposed stress creating greater reductions in task performance.

Self-doubts are worries about ability to attain a goal. Self-doubts can interfere with actions when thoughts about outcome expectations or self-efficacy are intrusive and are connected to the belief that one is unable to attain the goal at hand. The self-doubts interfere with normal self-regulatory processes that allow one to move forward in goal attainment (Schwartzer, 1996).

Individuals may also differ in the extent to which they are capable of filtering irrelevant information, leading to cognitive interference from relative distractibility. Furthermore, individuals who are stigmatized may experience higher levels of cognitive interference from worrying about what other people think of them. Physiological states, such as fatigue, substance abuse, and poor physical well-being, can also affect cognitive functioning, or can reduce the overall cognitive capacity of an individual (Sarason et al., 1996).

Self-Monitoring & Social Cognitive Theory

Albert Bandura (1986) provided a theoretical framework for analyzing human motivation, thought and action called Social Cognitive Theory. According to Bandura, in a social cognitive view human functioning is explained in terms of a model of reciprocality in which behavior, cognitive and other personal factors, and environmental events all react with one other. The term environment refers to the objective, external factors that can influence an individual's behavior. Social cognitive theory is helpful in understanding and predicting individual behavior and in identifying methods with which behavior can be changed.

Self-Regulatory Processes

Bandura examined the processes by which individuals regulate their behavior through internal standards and self-evaluative reactions to their own behavior (Bandura, 1986), leading to the development of three important self-regulatory constructs: self-monitoring, self-evaluation, and self-reaction. Self-monitoring occurs when individuals allocate attention to the actions and consequences of their behavior. Self-evaluation is the comparison of one's current performance to the desired level of performance, and the assessment of the discrepancy between them. Self-reaction processes are achieved by creating incentives and responding evaluatively to one's own behavior, according to an internal standard.

Self-regulatory processes are also considered processes by which individuals allocate attentional resources across tasks (Kanfer et al., 1994). For example, consider an individual who is exercising with two goals: to reach and maintain a certain heart rate, and to walk a certain distance within a given period of time. As the individual exercises, he uses a heart rate monitor, a watch, and a distance marker to monitor and evaluate his performance. The individual might notice that his heart rate has gotten too high, so he will slow down and spend more attentional resources on attending to the heart rate monitor. As he reaches his heart rate target, he may switch focus and realize that he needs to adjust his walking in an effort to meet his distance goal. As he monitors and evaluates his performance, he switches attentional resources from one task to another.

Several studies of attentional resources have indicated that self-regulatory processes themselves may require attentional resources, which could disrupt control processing of a task and negatively affect task performance (Steele-Johnson, et al., 2000; Kanfer & Ackerman, 1989; Kanfer et al., 1994). In particular, these studies posit that assignment of specific, difficult goals triggers higher levels of self-regulatory processes, and may detract attentional resources from developing necessary task strategies for completing the task.

A few studies have countered this determination by measuring "leftover" attentional resources during task performance and demonstrating that the self-regulatory processes themselves may not be responsible for the decrease in task performance. These studies contend that the goal-setting and performance evaluation components included in self-regulatory processes are highly automated due to extensive practice in everyday life (Lord and Levy, 1994). Therefore monitoring, detecting, and reacting to discrepancies should be able to be performed automatically. Rather, the reduction in performance may be due to the pressure to perform manifesting itself in inefficient rapid hypothesis testing and strategy switching (Earley et al., 1989).

For example, imagine that an individual is given a very difficult puzzle to solve in five minutes. She may begin with one strategy, and when it doesn't work within 30 seconds, she switches strategies in the hope that the new one will lead to progress. She may use her attentional resources during the task coming up with new strategies to try instead of focusing on one strategy and following it through.

Self-Efficacy

A key construct of SCT is self-efficacy, or the judgment of one's capability to accomplish a certain level of performance (Bandura, 1986). In terms of the concepts described above, self-efficacy may help explain the relationship between skill acquisition (a concept similar to Bandura's construct of behavioral capability) and task performance. Judgments of self-efficacy may be considered part of the self-reaction component of the self-regulatory processes described above. Therefore, some may consider judgments of self-efficacy to use attentional resources, while others may not.

Environment

Although it seems to be addressed to a lesser extent in the psychology literature, the environment plays a key role in cognitive processing, as well as in Social Cognitive Theory. The environment contains stimuli that can trigger automatic behaviors. As described above, once a task is automatized, it is more difficult to control or change. Therefore environmental stimuli that trigger automatic behaviors can be key in determining task performance, especially when the automatic behavior is counter to the task.

Allocation of Attentional Resources and Self-Regulation

Because an individual has limited attentional resources, it is important to consider how these resources are allocated between tasks. What determines which tasks are prioritized?

There are several factors that affect the allocation of attentional resources. A key concept in regards to resource allocation is motivation. Motivation refers to the direction of attentional effort, the amount of resources directed to the task, and the maintenance of that effort over time (Kanfer and Ackerman 1989, Campbell and Pritchard 1976, Humphreys and Revelle 1984, Kanfer 1987, Kleinbeck 1987). Motivational theorists have focused on the effects of factors such as dispositions, environments, incentive, goal assignments, and self-efficacy expectancies on intended effort, task behavior, and task performance (Bandura 1986, Campbell & Pritchard 1976, Ilgen & Klein 1988, Lawler 1973).

Some theories of motivation distinguish between two types of motivation. For example, Kanfer (1990) has proposed two cognitive resource allocation processes, distal motivation and proximal motivation. Kanfer describes proximal motivational processes as those that determine the distribution of effort during task engagement. Whereas distal motivational processes comprise the choice to engage any, some, or all of one's resources for attainment of a goal. Distal motivational processes therefore would, for example, determine whether tasks are attempted. According to Kanfer, distal motivational processes are determined by the individual's perceptions of how useful the performance of the task will be, how much effort is perceived to be required, and whether the amount of effort is worth the usefulness of the performance of the task.

In terms of cognitive function, forgetting and remembering are interesting processes that are also related to task demands and resource allocation. Interestingly, forgetting is considered critical for the efficient functioning of human memory (Storm, 07; Bjork and Bjork, 1988; Bjork, 1989; Macrae 1997). Without some means of getting rid of outdated or irrelevant information, it would become increasingly difficult to learn and access new and relevant information.

There is a dual function to the process of "remembering" that suggests two simultaneous subprocesses, one that brings items to attention and one that filters out everything else (Broadbent 1958). In other words, if we concentrate on attending to one thing, other things are filtered out. If we concentrate on suppressing one thing, we do it by attending to something else (Wegner and Schneider, 1989).

The self-regulation perspective of motivation (Boekaerts et al. 2005) focuses on goals and self-efficacy beliefs as main determinants of behavior. However, the role of self-efficacy and its relationship with task performance is not clear. While most researchers have found a positive relationship between self-efficacy and motivation or performance, others have found negative relationships (Vancouver et al. 2008). The positive relationship seems more intuitive—the higher an individual's self-efficacy, the more likely they are to allocate resources to and successfully complete a task (Bandura 1997).

However, Bandura also proposed that in early stages of skill acquisition lower self-efficacy may correlate with higher motivation, since the self-doubt may lead the individual to have more incentive to complete the task successfully. Other researchers propose that individuals with higher self-efficacy underestimate the discrepancy between the current and goal states of a task, and therefore allocate too few resources to the task (Vancouver 2001). Thus, while the role of self-efficacy is important, the relationship between it and motivation or performance is somewhat unclear.

Summary

Referring back to the simplified explanation of attentional resource capacity, assume that an individual has 100 units of attentional resources. How these resources are allocated and how well the tasks are performed depends on several factors. First, what things are affecting the individual's ability or overall capacity for task completion? It is possible that something such as fatigue has already reduced the individual's overall capacity before any tasks are attempted. Therefore the individual may only have 80 or 90 units of attentional resources that can be allocated. Furthermore, cognitive interference, such as worry about completing the task, may also take up attentional resources.

Second, how demanding are the tasks that need to be completed? The demand of the task depends on its complexity as well as the level of skill the individual has for the task. The combination of tasks, along with their complexity and the individual's level of skill will determine the demand on the attentional resources. For example, a task that is novel and difficult may use 60 units of attentional resources, while one that is well-practiced and simple may only take 10 units. A task that is so well-practiced that is has been automatized may require negligible units of attentional resources.

Finally, given that the task demands are higher than total attentional resources, how are the resources allocated to the separate tasks and how does this affect the individual's ability to successfully perform the task? If there are task demands totaling 150 units, but only 100 units of resources, the individual must choose between tasks or complete some tasks only partially.

References

Anderson, J.R. (1993). *Rules of the mind.* Hillsdale, NJ: Erlbaum.

Anderson, J.R. (1982). Acquisition of cognitive skill. *Psychological Review, 89(4),* 369-406.

Bandura, A. (1997). *Self-efficacy: the exercise of control.* New York: Freeman.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, N.J.: Prentice-Hall.

Bjork, E. L., & Bjork, R. A. (1988). On the adaptive aspects of retrieval failure in autobiographical memory. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory II*. London: Wiley.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger & F. I. M. Craik (Eds.) *Varieties of memory and consciousness: Essays in honour of Endel Tulving*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Boekaerts, M., Pintrich, P.R., & Zeidner, M. (2005). *Handbook of Self-Regulation.* San Diego, CA: Academic Press.

Broadbent, D.E. (1958). *Perception and Communication.* New York: Pergamon Press.

Campbell, J. P., & Pritchard, R. D. (1976). Motivation theory in industrial and organizational psychology. In M. D. Dunnette (Ed.), *Handbook of industrial and organizational psychology* (pp. 63-130). Chicago: Rand McNally.

Chaiken, S., & Trope, Y. (1999). Dual-process theories in social psychology. New York: Guilford Press.

Cohen, D.A., & Farley T.A. (2008). Eating as an automatic behavior. *Preventing Chronic Disease, 5(1).* Retrieved from http://www.cdc.gov/pcd/issues/2008/jan/07_0046.htm. Accessed August 15, 2009.

De Young, R. (2010). Stroop test. Retrieved from: http://www.snre.umich.edu/eplab/demos/st0/stroopdesc.html. Accessed March 15, 2010.

Dijksterhuis, A., Smith, P.K., van Baaren, R.B., & Wigboldus, D.H.J. (2005). *Journal of Consumer Psychology, 15(3),* 193-202.

Earley, P.C., Connolly, T., & Ekegren, G. (1989). Goals, strategy development, and task performance: some limits on the efficacy of goal setting. *Journal of Applied Psychology, 74,* 24-33.

Fitts, P.M. (1964). Perceptual-motor skill learning. In A.W. Melton (Ed.) *Categories of human learning.* New York: Academic Press.

Fitts, P.M., & Posner, M.I. (1967). *Learning and skilled performance in human performance.* Belmont CA: Brock-Cole.

Fu, W.-T. & Anderson, J. (2008). Dual learning processes in interactive skill acquisition. *Journal of Experimental Psychology, Applied. 14* (2), 179-191.

Gotlib, I.H., Roberts, J.E., & Gilboa, E. (1996). Cognitive interference in depression. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Humphreys, M. S., & Revelle, W. (1984). Personality, motivation, and performance: A theory of the relationship between individual differences and information processing. *Psychological Review, 91,* 153-184.

Ilgen, D. R., & Klein, H. J. (1988). Individual motivation and performance: Cognitive influences on effort and choice. Productivity in organizations, 143-176.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, N.J.: Prentice-Hall.

Kanfer, R. (1987). Task-specific motivation: An integrative approach to issues of measurement, mechanisms, processes, and determinants. *Journal of Social and Clinical Psychology, 5,* 237-264.

Kanfer, R. (1990). *Motivation and Industrial and Organizational Psychology.* Consulting Psychologist Press.

Kanfer, R., & Ackerman, P.L. (1989). Motivation and cognitive abilities: An integrative/aptitude-treatment interaction approach to skill acquisition

[Monograph}. *Journal of Applied Psychology, 74*, 657-690.

Kanfer, R., Dugdale, B., & McDonald, B. (1994). Empirical findings on the Action Control Scale in the context of complex skill acquisition. In J. Kuhl & J. Beckmann (Eds.), *Volition and personality: Action- and state-oriented modes of control* (pp. 61-77). Göttingen, Germany: Hogrefe & Huber Publishers.

Kleinbeck, U. (1987). The effects of motivation on job performance. In E Halisch and J. Kuhl (Eds.), *Motivation, intention, and volition* (pp. 261-271). New York: Springer-Verlag.

Klinger, E. (1996). The contents of thoughts: interference as the downside of adaptive normal mechanisms in thought flow. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Lawler III, E. E. (1973). Motivation in work organizations.

Lord, R.G., and Levy, P.E. (1994). Moving from cognition to action: a control theory perspective. *Applied Psychology: An International Review, 43,* 335-367.

MacLeod, C. (1996). Anxiety and cognitive processes. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Macrae, C.N., Bodenhausen, G.V., Milne, A.B., & Ford, R.L. (1997). On the regulation of recollection: The intentional forgetting of stereotypical memories. *Journal of Personality and Social Psychology, 72(4),* 709-719.

Miller, S.M. (1996). Monitoring and blunting of threatening information: cognitive interference and facilitation in the coping process. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Newell, A. (1990). *Unified theories of cognition.* Cambridge, MA: Harvard University Press.

Paas, F.G.W.C., & Van Merrienboer, J.J.G. (1994). Instructional control of cognitive load in the training of complex tasks. *Educational PsychologyReview, 84,* 426-434.

Parasuraman, R., & Davies, D. R. (Eds.) (1984). *Varieties of attention*. Orlando: Academic Press.

Sarason, I.G., Pierce, G.R., & Sarason, B.R. (1996). Domains of cognitive interference. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Schneider, W., Dumais, S. T., & Shiffrin, R. M. (1984). Automatic and control processing and attention. In R. Parasuraman & D. R. Davies (Eds.), Varieties of attention (pp. 1-27). Orlando: Academic Press.

Schneider, W., & Shiffrin, R.M. (1977). Controlled and automatic human information processing: I. Detection, search and attention. *Pyschological Review, 84,* 1-66.

Schwartzer, R. (1996). Thought control of action: interfering self-doubts. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Shiffrin, R.M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Preceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127-190.

Steele-Johnson, D., Beauregard, R. S., Hoover, P. B., & Schmidt, A. M. (2000). Goal orientation and task demand effects on motivation, affect, and performance. J Appl Psychol, 85(5), 724-738.

Storm, B.C., Bjork, E.L., & Bjork, R.A. (2007). When unintended remembering leads to unintended forgetting. *Quarterly Journal of Experimental Psychology, 60(7)*, 909-915.

Vancouver, J.B., Thompson, C.M., & Williams, A.A. (2001). The changing signs in the relationships among self-efficacy, personal goals, and performance. *Journal of Applied Psychology, 86*, 605-620.

Vancouver, J.B., More, K.M., & Yoder, R.J. (2008). Self-efficacy and resource allocation: support for a nonmonotonic, discontinuous model. *Journal of Applied Psychology, 93 (1),* 35-47.

Wegner, D. M., & Schneider, D. J. (1989). Mental control: The war of the ghosts in the machine. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended Thought* (pp. 287-305). New York: Guilford Press.

Wood, R. E. (1986). Task complexity: Definition of the construct. *Organizational Behavior and Human Decision Processes, 37(1).*

Yee, P.L., and Vaughan, J. (1996). Integrating cognitive, personality, and social approaches to cognitive interference and distractibility. In I.G. Sarason et al. (Eds.) *Cognitive Interference: Theories, Methods, and Findings.* Mahwah, NJ: Erlbaum.

Recommended Citation:

Bhargava, T. D. (2020, July). *Overview: The science of bandwidth*. Everyday Bandwidth. http://everydaybandwidth.com/the-science.html.

