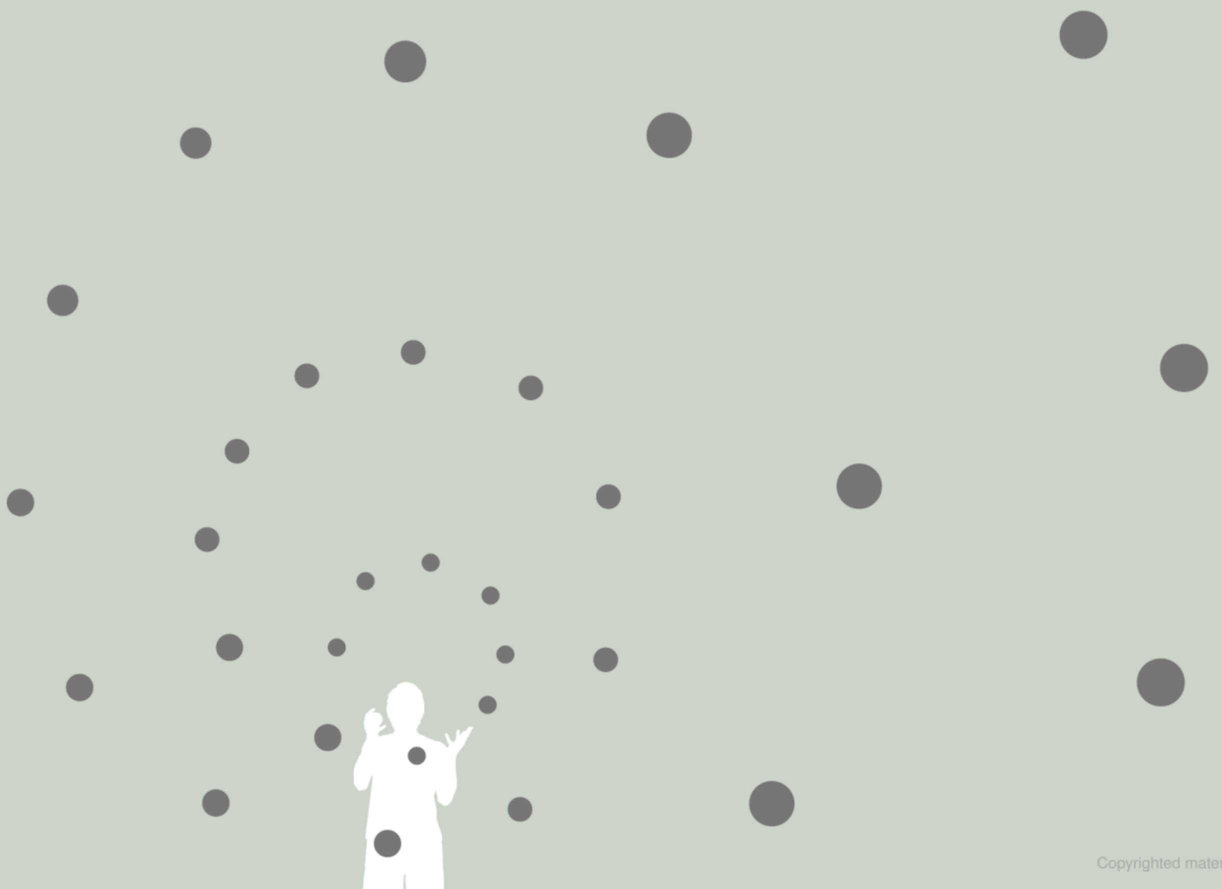
Effortless Attention

A NEW PERSPECTIVE IN THE
COGNITIVE SCIENCE OF
ATTENTION AND ACTION

EDITED BY

Brian Bruya



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Introduction: Toward a Theory of Attention That Includes Effortless Attention and Action

Brian Bruya

Attention and action require effort, and, under normal circumstances, the higher the demands of a course of action, the greater the effort required to sustain a level of efficacy (Grier et al. 2003; Kahneman 1973). Although a clear distinction is rarely made, effort is generally presumed to be both objective (as calories consumed) and subjective (as experienced effortfulness). There are times, however, when attention and action seem to flow effortlessly,[1] allowing a person to meet an increase in demand with a sustained level of efficacy but without an increase in felt effort—even, at the best of times, with a decrease (Csikszentmihalyi 1975; Csikszentmihalyi and Csikszentmihalyi 1988; Dobrynin 1966).

Under normal circumstances, the expectation is that expenditure of effort increases with the level of demands until effort reaches a maximum point at which no more increase is possible (Kahneman 1973; see figure I.1).

Sometimes, however, when the level of demand reaches a point at which one is fully engaged, one is given over to the activity so thoroughly that action and attention seem effortless (see figure I.2).

That subjective effort can follow this path of unexpected decrease without a decrement in performance is clearly supported by the literature (Csikszentmihalyi, this volume; 1975; Dormashev, this volume; Ullén, this volume; Csikszentmihalyi and Csikszentmihalyi 1988; Dobrynin 1966; Jackson and Csikszentmihalyi 1999). Whether objective effort follows the same path is less clear, but there is evidence to suggest that it is possible (Wulf and Lewthwaite, this volume). Either way, because the objective–subjective distinction is rarely made in regard to discussions about effort, evidence shows that the accepted theoretical framework of increased effort to meet increased demand falters. This failure of our accepted framework to accommodate effortlessness has likely been the reason for its long neglect as a subject of serious investigation and for artists and philosophers to attribute its causes to the mystical, the divine, or the Freudian unconscious.

Mihaly Csikszentmihalyi (1975) identified the phenomenon of effortlessness as autotelic experience—when a person's full engagement in an activity provides ongoing

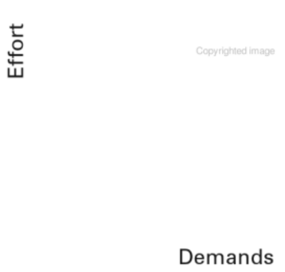

Figure I.1
Effort versus demands in effective action—normal experience.

Figure I.2
Effort versus demands in effective action—effortless experience.

impetus for attention and action—and found it across a wide variety of activity domains, from rock climbing to chess, from factory line working to intimate conversation.[2] Using a novel data collection procedure (Hektner, Schmidt, and Csikszentmihalyi 2007) that allowed for better monitoring of naturalistic activities, Csikszentmihalyi achieved a great deal on the descriptive level, isolating the phenomenon and detailing the manner of its occurrence, its duration, its depth, its phenomenal characteristics, its variability, its breadth across populations, its parameters of occurrence, and its psychological value. Through his work, autotelic experience (commonly known as "flow") has entered both the scientific and the vernacular vocabularies (see box I.1 for

Box I.1

Example

A professor who has given the same classroom lecture 10 times over the past five years gives it again on two occasions over two semesters.

Effortful Experience

Outside of class, the professor is struggling with a particularly trying bit of research, a student he failed for cheating has taken the matter to the administration, a recent faculty meeting exploded in accusations and acrimony, and a close family member is ill. Inside of class, he is in an unfamiliar room, his new shoes are hurting his feet, the temperature is unusually warm, and students are lethargic. Under these conditions,* the professor experiences a frustrating lecture. Examples fall flat, insightful points come haltingly, if at all, and conclusions feel awkward and indecisive. Unexpected questions from students are met with hems and haws. There is a feeling of self-consciousness—that the lecture is not going well. There is a feeling of interminability during the lecture and of relief and fatigue after the lecture.

Effortless Experience

Outside of class, the professor just sent off a revised manuscript for publication, he recently won an award for teaching excellence, and his new research assistant is buoyant and eager. Inside of class, conditions are familiar, and students are responsive. The lecture goes smoothly, punctuated at appropriate moments by examples and insightful asides that meet bright eyes and nods of understanding. Unexpected questions are deftly assimilated to the material with humor and aplomb. Conclusions neatly wrap up sections and lead naturally to subsequent sections. There is no feeling of self-consciousness during the lecture but a retrospective feeling of diminished sense of time and that the lecture came off automatically and with ease. There is a feeling after the lecture of zest and that it could have been continued indefinitely without fatigue.

* There are many possible obstacles to effortlessness; others could be extreme demands, low demands, lack of interest, unexpected interruptions, lethargy, negative affect, and so on. (The effect of unfavorable conditions is not a necessary one. Conceivably, in the first experience the professor could have overcome the obstacles and experienced an effortless lecture.)

an illustration of how the same activity can be carried out with and without a feeling of flow).

Because of its occurrence largely in naturalistic settings, however, and perhaps due to its vestigial mysteriousness, autotelic experience has been resistant to explanatory analysis. Therefore, fundamental questions regarding the cognitive science of effortlessness have, until now, been neither asked nor answered.

In a separate program in the Soviet Union, descriptive research was conducted by N. F. Dobrynin, D. I. Gatkevich, and N. V. Lavrova (Dobrynin 1966; Dormashev, this volume) under the rubric of postvoluntary attention—attention that was neither voluntary (effortful) nor involuntary (automatic). Postvoluntary attention is characterized in the literature as attention that has been captured by an absorbing, interesting, and meaningful activity and that can be sustained willingly and productively for a long period of time. Unfortunately, the bulk of this literature remains untranslated.

Despite the difficult questions remaining, research into effortless attention and action should be viewed not as an esoteric discipline but instead as a welcome challenge to test, refine, and even alter current models of attention and action. In order for any model of behavior to be considered comprehensive, it must be able to account for all types of human action. As Daniel Kahneman and Anne Treisman have said, "While we continue to work within the old framework [of attention], we should remain alert to the possibility that it could soon become obsolete" (Kahneman and Treisman 1984, p. 57). Bernhard Hommel recommends that in order to make future advances in developing a full model of human action, our most basic concepts must be clarified (Hommel 2007). The present volume submits the concept of effortless attention for such consideration.

In this introduction, I isolate seven topics concerning which scholars have produced theories and results pertinent to a nascent theory of effortlessness. I offer a summary of these ("Overview"), show how the topic of effortlessness may reveal gaps in the current literature and challenge current theoretical models ("Challenges–Gaps"), delineate potential aspects of a future theory of effortless attention and action ("Theory"), and discuss how the chapters in this volume mark advances in that direction ("Advances"). The categories do not necessarily reflect the intentions of the contributors or fully encompass current paradigms in cognitive science, and they are best considered one possible attempt at a heuristic for approaching this unwieldy topic. Further, the "Advances" discussions are necessarily brief and discuss how each chapter contributes to our understanding of only one issue in particular. Readers will find that the chapters are usually broader than that, often speaking importantly on several of these issues.

stances attention and self-regulation draw from a shared limited resource. Research with colleague Gailliot (Gailliot et al. 2007) suggests that this resource is glucose. Thus, under normal circumstances, objective mental effort (in the form of attention and self-regulation), like objective physical effort, appears to have a measurable and manipulable physiology.

2. *Decrease in objective effort during attention* Gabriele Wulf and Rebecca Lewthwaite show in this volume that the normal reduction in physical and mental objective effort (coupled with an increase in efficacy) that is achieved through typical diachronic practice can be enhanced synchronically. Through a slight shift in the focus of attention—from internal to external—subjects have consistently decreased their objective effort while increasing their efficacy. In other words, there is a direct correspondence between attention and effort such that both physical and mental effort can be reduced while one's prior level of attention is maintained.

Topic 2: Decision Making

Overview

The study of decision making is now a mainstay of economics research (Tomlin et al. 2006) and moral psychology (Greene, Nystrom, Engell, Darley, and Cohen 2004). Less attention has been focused on the fact that every action a person makes involves a choice of some kind, whether fully conscious or not. Jeffrey Schall has shown that choice (selection from among alternatives) is conceptually dissociable from both decision making (deliberation about selection) and action (overt indication of selection; Schall 2001).

Working within a more traditional framework, Mariano Sigman and Stanislaus Dehaene have reported that of the three stages of an action (perceptual, central, and motor), the first and third can work in parallel on different stages of different tasks, and only the central must work serially, hence accounting for time delay in deliberative action (Sigman and Dehaene 2005).

A link between the autonomic nervous system and automatic action was rarely considered until Antonio Damasio and colleagues demonstrated that the autonomic nervous system plays a crucial role in some forms of decision making that lead to action (Damasio 1996, 1994). In essence, the autonomic nervous system sets the body and mind in proper form for reacting to uncertain but familiar circumstances.

A key component of automaticity is an individual's level of response inhibition. Antoine Bechara, working with Damasio, has conducted seminal research into the role of response inhibition in decision making (Bechara, Damasio, Tranel, and Damasio 1997; Bechara, Damasio, and Damasio 2000, 2003; Bechara 2004). In impulsive behavior, according to Bechara, response inhibition fails, the decision-making process never engages, and a response based on previous success is initiated automatically. Different areas of the brain, he says, may be active, depending on which of three types of decision (under certainty, under risk, and under ambiguity) is being made. If decisions under ambiguity are more likely, they will involve the orbitofrontal region and thereby engage the autonomic nervous system, which would slow processing down considerably.

Arne Dietrich has postulated that autotelic experience involves a decrease of neural activity in executive regions of the brain, specifically the anterior cingulate cortex (Dietrich 2004), which has been confirmed to be directly associated with the feeling of effort (Mulert, Menzinger, Leicht, Pogarell, and Hegerl 2005).

Challenges–Gaps

The above findings suggest that a complete theory of choice and decision making in human behavior would do well to include the actual neurophysiology of such processes. Effortless attention complicates any such model because the distinction between executive control and decision making vanishes. Decision making in flow is fast and precise, implicating automatic action, but also creative and flexible, implicating processes that are normally associated with executive control—though executive control processes are generally considered slow. Monitoring activation of brain areas in effortless attention may shed some light.

Theory

Recognizing Schall's distinction between choice, decision making, and action and then identifying the neural mechanisms underlying each may be important in accounting for the precision of effortless action and the rapid choices that precede it. Under Sigman and Dehaene's model, does effortless action (where rapid and accurate responses are characteristic) leave out the middle—deliberative—step, is it somehow integrated in a parallel fashion, or is there another way to account for it? Damasio and Bechara's work may point to an important role for something like confidence in effortlessness—familiarity with an activity and confidence in one's ability may (artificially?) push the subjective level of engagement from ambiguity toward certainty.

Advances

1. *Response conflict, effort, and decision making* In their contribution to this volume, Joseph McGuire and Matthew Botvinick show that an integral part of the decision-making process involves evaluating the demand for cognition in a prospective task. Drawing on numerous studies, they postulate that the anterior cingulate cortex and nearby medial frontal cortex monitor the current output of cognitive resources and compare that to expected demand, resulting in a projected increase or decrease in needed cognition. This projected amount of control is then balanced against projected reward (nucleus accumbens), resulting in either an adjustment in cognitive resources

to meet expected demand or in avoidance. McGuire and Botvinick demonstrate, therefore, that mental effort is dissociable from cognitive control. Cognitive control is an ongoing process, and subjective mental effort is associated with the change in that process rather than with the process, itself. This shows us how it is possible that there can be a high level of cognitive control but a low level of subjective effort.

2. *Effort in deliberative problem solving* It is natural to think that the greater the effort applied to a task, especially one that is exclusively cognitive, the better the outcome will be. Marci DeCaro and Sian Beilock demonstrate that although effortful (i.e., linear, rule-based) problem-solving strategies often result in better performance, under real-world conditions they can lose out to less effortful (i.e., associative, heuristic) strategies. Such results provide another avenue for demonstrating that effortful attention and performance are dissociable.

3. *Executive control is not necessarily conscious* The status of executive control as a defining feature of the explicit processing system is called into question by Chris Blais. Blais shows through his research and studies by others that an instance of executive control that is generally taken as a paradigm case of executive control by researchers actually occurs outside of conscious awareness. Blais, therefore, calls into question the need for a distinction between explicit and implicit systems of control. The very phenomenon of effortless attention, as explained above, seems to lead in the same direction, and Blais's work may help in resolving this conundrum.

Topic 3: Action Syntax

Overview

Joaquín Fuster has examined the temporal role of executive function in attention and action, in which the automated behavior that is integrated into lower neural stages (premotor cortex, basal ganglia, hypothalamus, or other subcortical structures) is activated and modulated by the anterior cingulate cortex (high motivation, resolution of conflict), areas of lateral prefrontal convexity (set, integration of information across time), and orbital areas (inhibitory control). Temporal integration of behavior, Fuster says, is closely related to negotiating a syntax. Although syntax is most commonly associated with language, Fuster says that "linguistic syntax and motoric syntax seem to have a common phyletic origin" (Fuster 2003, p. 180). If the perception–action cycle involves the same, or functionally similar, neural mechanisms as those that allow us to negotiate grammar, it would go a long way in explaining certain elements of effortless action.

Matthew Botvinick (Botvinick and Plaut 2004; Botvinick 2007) has developed a recurrent connectionist network model that accounts for decision-making behavior in everyday routine tasks through transient, flexible hierarchies that rely on concurrent representation rather than enduring schemas. The resulting hierarchies are context dependent and, as such, are appropriately vulnerable to distraction errors common in everyday behavior. Such a computational model may help elucidate the role of attention in complex sequential actions.

Among other things (Ivry and Helmuth 2003), sequential actions involve neural timing mechanisms, particularly in the cerebellum (Ivry 1997; Ivry and Richardson 2002; Ivry, Spencer, Zelaznik, and Diedrichsen 2002; Ivry and Spencer 2004a; Ivry and Spencer 2004b; Spencer, Ivry, and Zelaznik 2005), neural systems for force control and special trajectory planning (Diedrichsen, Verstynen, Hon, Zhang, and Ivry 2007; Spencer et al. 2005), and response selection (Bischoff-Grethe, Ivry, and Grafton 2002; Diedrichsen, Verstynen, Hon, Lehman, and Ivry 2003).

Challenges–Gaps

Syntax consists in a set of goals arranged in a hierarchy (within a circumscribed domain) that is constituted by defeasible rules temporally executed. Since effortless action is most often achieved in a well-demarcated activity, with constitutive rules, effortlessness (of attention and action) may be closely related to the process of negotiating syntax. The notion of action syntax is still a novel one and must be integrated into any comprehensive model of action (Costanzo 2002). One important issue that it brings to the fore is the distinction between explicit rule following and optimal action within constraints (Langlois 1998). When adding cream and sugar to a cup of coffee (Botvinick and Plaut 2004), how does one decide which to add first? When playing a sequence of notes on the piano, how does one decide on the particular dynamics? Assimilating explicit rules (Bunge 2004) is only one step in executing action. Another step is applying the rules appropriately according to context, which can never be completely identical from one instance to the next.

Theory

A theory of effortlessness should embrace action syntax and explain at functional and physiological levels what it means to negotiate a syntax. It should distinguish between explicit rule syntax and constraint–parameter syntax and thereby account for the role of appropriateness in effective action (how quickly to stir, how much arc to put on the basketball, how to express a chord, whether to bluff or not, etc.). Such a theory should also elucidate the role of attention in complex, sequential actions. Where, when, and how is attention directed to relevant cues, and how is that relevance determined? Further, determining these aspects of attention will have important implications for training and education.

Advances

1. *Action representation drives attention* Where is one's attention in downhill skiing? The pace of the activity is too fast for deliberation in conscious processing, and yet we

do attend fleetingly to this curve and that bump. Bernhard Hommel offers a theory for conceiving of attention not as necessarily consciousness driven and not as a system for managing scarce cognitive resources but as a "by-product of action control in a distributed processing system" (chapter 5, this volume). Hommel demonstrates that at its most fundamental level, attention is the process of perceptual systems filling parameters in preestablished action programs as those action programs successively come online. A skier (on a good day) attends effortlessly to curves and bumps as needed to maintain success. Attention, according to Hommel, is normally experienced as effortless, and it is only when something comes between endogenous motivation and relevant external cues (as in artificial laboratory tasks) that it is experienced as effortful. The apparent integration of perception and action in a single representational system appears to allow for immediate action-driven processing of syntactic cues.

2. *Effortlessness as domain specific* Through their unique methods of measuring dimensions of activities under normal circumstances, Mihaly Csikszentmihalyi and Jeanne Nakamura in their contribution to this volume demonstrate that effortless attention is most likely to be achieved under domain-specific conditions: clear, sequential, short-term goals; immediate feedback; and a balance between opportunities for action and the individual's ability to act. When these conditions are met under conducive circumstances, effortless attention is most likely to ensue. Further, they show that in circumstances of high attention experienced as effortless (as opposed to high attention experienced as effortful), subjects feel more involved, in control, unselfconscious, relaxed, and as if they are putting their skills to more use.

3. *Effortless attention in the lab* Can these conditions be replicated in the laboratory? While Hommel suggests that the limitations of the laboratory setting are problematic in understanding effortless attention, and while Csikszentmihalyi and Nakamura have overcome those limitations by taking their research outside the lab, there is still something to be said for the prospect of introducing a naturalistic activity into the lab such that effortless attention can be induced in a setting that would allow for more systematic study and more intense monitoring. In their contribution to this volume, Arlen Moller, Brian Meier, and Robert Wall examine the attempts of several laboratories, including their own, to induce flow by manipulating the balance between challenge and skills for subjects playing video games. While these teams have been successful in inducing many of the features of flow, the laboratory setting, itself, still presents a number of challenges. Moller, Meier, and Wall go on to examine such challenges and formulate suggestions for future research.

4. *Syntax and the draw of attention* In his contribution, Brian Bruya offers a new model of attention. Rather than a spotlight, or a filter, and so on, this model posits that attention may be profitably conceived of as a mechanism of sensitization that draws information relevant to dynamic contextual structures of reference through dynamic processing pathways. Contextual structures of reference compete spontaneously for

managerial levels (Dobrynin 1966) be cultivated and encouraged for the sake of the acting agent?

Moving from the individual agent to the social agent, social behavior involves executing appropriate actions according to complex circumstances—evaluating subtle cues and responding without time for deliberation. Insofar as mirror neurons have been implicated in social action, as Hurley (among others) has done, many questions can be asked with regard to how much of social behavior is automatic and how much is voluntary and with how much robustness this distinction can even be maintained. Are the same mechanisms of effortless action also at work in social action (see also under "Automaticity" below)? If so, given that effortless attention and action are often cultivated in a practice regime, what are the implications for the possibility of achieving expertise in social action? Could such knowledge be applied at a personal or even a pedagogical level? What are the ethical implications?

Theory

Effortless attention and action may simply be the free running of Freeman's intentional system, but what does that mean for a persistent sense of self, especially if such a sense of self falls away during effortless activity? Because reports of effortlessness often involve the loss of coherence of a phenomenal sense of self (Csikszentmihalyi 1975; Csikszentmihalyi and Csikszentmihalyi 1988; the feeling that the piano is playing itself or one is on "autopilot"), some aspects of functional selfhood seem to dissociate also. A comprehensive theory of perception and action would account not only for the role of the self in motivation but for the dissolution of the self in effortless attention and action. Further, it would explore the implications of "nonagentive" action in ethics, education, law, and public policy.

Advances

1. *Self and the thalamus* An important repository of anecdotal and speculative literature regarding effortless attention and action lies in the Asian philosophical traditions. In Zen Buddhism, for example, there are countless stories of acolytes who have practiced meditation for long periods and then, on encountering an unexpected, nondescript stimulus, suddenly experience a number of the hallmarks of effortless attention. In his contribution to this volume, neurologist James Austin considers how the sudden experience of a dropping away of a sense of self may have direct neurophysiological correlates. Drawing on research that distinguishes two attentional systems, he shows that distinct pathways between thalamic nuclei and the two attentional systems are likely implicated in the experience of a loss of a sense of self. He suggests that the blinking out of self-consciousness in a Zen enlightenment experience, and in effortless attention and action more broadly, may be due to deafferented cortical areas of the dorsal (egocentric) attentional system, traceable to deactivated thalamic nuclei. The

entire process is achieved, he suggests, through long practice regimens and their resulting neurophysiological effects.

2. *Ethics and agency* The findings in cognitive science that call into question the traditional conception of a unitary rational agent have profound implications for contemporary ethical theory. In his contribution to this volume, Edward Slingerland integrates results from the cognitive science of action with an ethical theory that takes effortless action to be the epitome of virtuous action. Through a detailed examination of philosophical and cognitive scientific accounts of human action, Slingerland concludes that ethical human action is best characterized on a descriptive level in terms of a virtue ethics broadly construed. In other words, he says, humans generally act not from active cognitive control but from self-activating effortless dispositions that can be cultivated through introspection and education.

3. *The person level in activity* Researchers in twentieth-century Russian psychology recognized the primary importance of syntax in attention and action, adopting the rubric *activity theory* to describe their overall psychological framework. Yuri Dormashev, in addition to giving an extraordinary introduction to activity theory in general and postvoluntary attention in particular, explains in his contribution to this volume that attention is best understood in terms of activity, functioning as a *gestalt* and focused on a limited range of objects. In postvoluntary attention, activity is organized at the person level, or *personality* (understood as the focal point of the driving hierarchy of motives in the cultural sphere). On this basis, Dormashev suggests that an important element missing from accounts of autotelic experience is that of *personal taste*—the interest, or broad aesthetic sense, that acts as a motivating force outside of organic and social motivations. The sense of transactional, embedded attention and action inherent in this view serves to unify the autonomous individual with the social and organic milieus in which—and through which—the individual develops.

Topic 5: Automaticity

Overview

Kahneman and Treisman point out that there has been a running debate among researchers of attention as to the role of automaticity in attention, with some researchers emphasizing early onset attention (selective processing–filtering) and some late onset (mental set/efficiency of action), and suggest that research into automaticity may help us bring the two closer together and away from mutual exclusivity (Kahneman and Treisman 1984; see also Pashler 1998).

In his analysis of available data, Marc Jeannerod (2006) suggests that the automated steps of an action come in for conscious access when there is discord between intention and actuality—when the perceptual representation does not match the action representation.

John Bargh, researching the automaticity of social behavior, has concluded that much more of behavior than previously thought is outside of voluntary consciousness (Bargh 2000; Bargh and Chartrand 1999). He has recently proposed that a cascade model of language be applied to behavior (Bargh 2006; Ackerman and Bargh, this volume), explaining how actions proceed spontaneously from parallel processed goal activation, just as conversation occurs spontaneously while also being goal directed and falling within strict syntactic and semantic parameters.

Related to the cascade model is the theory of event coding put forward by Hommel, Müsseler, Aschersleben, and Prinz (2001; Hommel, this volume). Working in the tradition of Dewey (1896) and Gibson (1979), they suggest, as discussed briefly above, that perception and action are encoded in the brain in unitary fashion, accounting for the functional linking of the two as one. One result of this model is the postulate that actions are encoded in terms of their effects rather than in terms of explicitly understood movements. The practical result of this is that attention in learning an action must be focused not on the intentional, voluntary aspect of a movement but on the effects of the movement (Wulf 2001, this volume).

Challenges–Gaps

These theories and findings, coupled with those under "Agency" and "Action Syntax" above, highlight a shift in research models from stimulus–response to what one might call sensitivity–responsiveness. Whereas the behaviorist model cut out intentional agency completely, the new models replace it with a multimodal agent, which, while not exactly being metaphysically free, is a bundle of preafference and readiness potentials created in a complex array of self-organized neuronal populations, with their representational (or other) associations constantly arranged and rearranged through phylogenetic and historical factors. In many circumstances, the responsiveness of the agent appears to be a function of these associations.

Theory

If Jeannerod is correct that actions come into consciousness when perception does not match intention, it would help explain why effortless action, which reportedly occurs when expectations are consistently met, often seems outside of conscious awareness. On the other hand, it would also seem to leave high-level effortless action as purely automated, thereby seeming to preclude credit to a subject for creativity, insight, emotional expression, and so forth. A cascade model of behavior may work well for effortless action; in fact, effortless action, being generally domain dependent, may prove to be the best testing ground for establishing the basis for such a theory. The theory of event coding may help explain why the precision of effortless action can appear "nonintentional" while attention is intensely focused on rapidly arising cues.

Advances

1. *Social automaticity* In their contribution to this volume, Joshua Ackerman and John Bargh review the extensive literature on the automaticity of social coordination, suggesting three general mechanisms that may account for it: simple dynamical systems at the level of mechanics (e.g. synchronized rocking in rocking chairs), shared perception–action representations (e.g., priming), and active motivations. They conclude that the automaticity of social coordination has several qualities that may be relevant to corollary qualities in flow: reduced experience of effort, transcendence of the negative aspects of the self, positive affect, and interpersonal fluency. Ackerman and Bargh go on to make a case for flow's being a special case of automaticity, explaining that the conscious awareness does not, itself, drive the experience of flow and is, instead, a passive spectator.

Topic 6: Expertise

Overview

Attention and its relation to performance have been an intense topic of research, exemplified by the conference and volume *Attention and Performance*'s appearing biennially since 1966. There appears to be a very close link between expert performance and effortlessness. Although the learning of a highly refined skill involves intense effort over extended periods (Ericsson and Lehmann 1996), its execution at the highest level is often characterized from a first-person perspective as feeling effortless and from a third-person perspective as appearing effortless. How to build this level of expertise and how it is executed have been the object of a number of interesting lines of research.

For instance, Sian Beilock and colleagues (Beilock, Bertenthal, McCoy, and Carr 2004; Beilock, Carr, MacMahon, and Starkes 2002) have found, when comparing sport performance of novices and experts, that experts perform better at full attentional capacity, even if their attention is occupied by irrelevant details, such as distractors or an artificial speed requirement.

Focused attention is attention that is voluntarily concentrated on a single domain of stimuli. The limited attention of lower animals can be understood as involuntarily focused attention. Ethologist Reuven Dukas (2002) has suggested that limited attention in lower animals may have an adaptive advantage, and Csikszentmihalyi (1978) has noted the advantages of focused attention in autotelic experience. Drawing from a series of studies involving computer simulations, Dehaene and Changeux (2005) have postulated that when human attention is captured in high-level cortical activity, the processing of domain-specific stimuli is facilitated while that of other stimuli is inhibited, perhaps accounting for the phenomenon of inattentional blindness.

Challenges–Gaps

Effortlessness is often characterized by an experience of completely focused attention. It is a mystery, however, as to why attempting to give full attention to an activity at which one is completely competent and which *does not require* full attention should result in a performance decrement. It may be that sustaining full attention in a task that does not demand it is simply not possible for any length of time (but why?) and that free cognitive resources will be involuntarily drawn to competing targets of attention, drawing with them some of the cognitive resources required for the original task.

Theory

The Dehaene and Changeux model (2005) seems to most easily match autotelic experience—as opposed to normal experience—because full attention that inhibits non-domain stimuli is difficult to maintain outside of autotelic experience. A theory of effortlessness should include the mechanisms for the capture and release of full attention in autotelicity and seek to answer the question of whether the capturing can be facilitated or the releasing can be inhibited through training.

Advances

1. *The explicit system and perfectionism* Related to the chapters by Austin, DeCaro and Beilock, and Wulf and Lewthwaite mentioned above, the contribution to this volume from Arne Dietrich and Oliver Stoll considers evidence, first, for the downregulation of specific brain areas during effortless attention and, second, for the important relationship between attention and performance. Dietrich and Stoll begin by explaining the explicit–implicit distinction in cognitive processing and suggest that some activities can facilitate a neurophysiological process that shuts down modules of the explicit system. They then weigh in on the long-standing issue of the value of perfectionism by distinguishing two kinds, one of which draws processing through the explicit system and the other through the implicit system—the former being deleterious in attempts to achieve flow.

2. *The physiology of flow* Related to the work of Moller, Meier, and Wall described above, Fredrik Ullén, Örjan de Manzano, Töres Theorell, and László Harmat have successfully induced flow in the lab and examined its physiological correlates. Through these studies, they have found that the physiological correlates (measured in skin conductance, electromyography of facial muscles, and respiratory and cardiovascular dimensions) of effortless attention are, indeed, unique, sharing some features with the state of joyous arousal and importantly distinct from the state of effortful attention. Through further measurements of personality traits, including flow proneness, they found that flow proneness is not correlated with the capacity for sustained effortful attention, nor with general intelligence in leisure activities, and is negatively correlated with general intelligence in maintenance and professional activities.

A complete theory of effortless attention and action would include not only precise definitions of basic terms of attention but also a taxonomy of stages of attentional training.

Advances

1. *Evidence for improved attention through general training* In their contribution, Michael Posner, Mary Rothbart, M. R. Rueda, and Yiyuan Tang trace measurements of temperamental effortful control in parents and children to specific brain networks and the brain networks to specific gene alleles, demonstrating natural individual differences in attentional capacity. They go on to demonstrate that these differences can be significantly influenced through environmental factors. Testing the potential of attentional training, Posner and colleagues found that five days of computerized task training in young children can result in increased activity in the anterior cingulate cortex, a general and persistent increase in IQ, and an increase in affective regulation. In adults, in a double-blind study in which subjects were trained for only 20 minutes per day over five days in a systematic method of mind–body attention, subjects showed improvement in executive attention, lower negative affect, lower fatigue, and lower stress compared to both controls and subjects who underwent generic relaxation training.

Conclusion

The phenomena of effortless attention and action provide an unexplored opportunity to test and probe current models of attention and action and extend them in directions that not only are valuable academically but could potentially have a significant impact on human flourishing. Each of the chapters in this volume has implications that bear on a variety of different aspects of attention and action discussed above.

Notes

1. Reduction in effort is often associated with a concomitant reduction in attention (Dehaene, Kerszberg, and Changeux 2001). Here, however, "effortless" means a reduction of felt effort only, with attention preserved or even enhanced.

2. Action in autotelic experience should be distinguished from overlearned action. Overlearned action is a reduction in effort in the face of a sustained high level of challenge within a domain *diachronically*, whereas action in autotelic experience is a reduction in effort in the face of a sustained high level of challenge *synchronically*. The execution of action in autotelic experience typically depends on overlearned action, whereas overlearned action does not necessarily entail the achievement of autotelic experience. Also, overlearned action seems to reduce effort by bring-

ing action out of attention, freeing up cognitive resources for other things, whereas autotelicity is marked by the paradox of minutely sensitized attention coupled with a diminution of subjective will.

3. If objective effort in autotelic experience is found to decrease along with subjective effort, while efficacy is maintained, the standard models would be challenged even more radically.

References

Austin, J. H. 1998. *Zen and the brain: Toward an understanding of meditation and consciousness*. Cambridge: MIT Press.

Austin, J. H. 2006. *Zen-Brain Reflections*. Cambridge: MIT Press.

Bargh, J. A. 2000. Beyond behaviorism: On the automaticity of higher mental processes. *Psychol. Bull.* 126:925–945.

Bargh, J. A. 2006. Agenda 2006: What have we been priming all these years? On the development, mechanisms, and ecology of nonconscious social behavior. *Eur. J. Soc. Psychol.* 36:147–168.

Bargh, J. A., and T. L. Chartrand. 1999. The unbearable automaticity of being. *Am. Psychol.* 54:462–479.

Baumeister, R. F., E. Bratslavsky, M. Muraven, and D. M. Tice. 1998. Ego depletion: Is the active self a limited resource? *J. Pers. Soc. Psychol.* 74:1252–1265.

Baumeister, R. F., and K. D. Vohs. 2005. *Handbook of self-regulation: Research, theory, and applications*. New York: Guilford Press, 2004.

Bechara, A. 2004. The role of emotion in decision-making: Evidence from neurological patients with orbitofrontal damage. *Brain Cogn.* 55:30–40.

Bechara, A., H. Damasio, and A. R. Damasio. 2000. Emotion, decision making and the orbitofrontal cortex. *Cereb. Cortex* 10:295–307.

Bechara, A., H. Damasio, and A. R. Damasio. 2003. Role of the amygdala in decision-making. *Ann. N. Y. Acad. Sci.* 985:356–369.

Bechara, A., H. Damasio, D. Tranel, and A. R. Damasio. 1997. Deciding advantageously before knowing the advantageous strategy. *Science* 275:1293–1295.

Beilock, S. L., B. I. Bertenthal, A. M. McCoy, and T. H. Carr. 2004. Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychon. Bull. Rev.* 11:373–379.

Beilock, S. L., T. H. Carr, C. MacMahon, and J. L. Starkes. 2002. When paying attention becomes counterproductive: Impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *J. Exp. Psychol. Appl.* 8:6–16.

Bengtsson, S. L., Z. Nagy, S. Skare, L. Forsman, H. Forssberg, and F. Ullén. 2005. Extensive piano practicing has regionally specific effects on white matter development. *Nat. Neurosci.* 8:1148–1150.

Bischoff-Grethe, A., R. B. Ivry, and S. T. Grafton. 2002. Cerebellar involvement in response reassignment rather than attention. *J. Neurosci. the Official Journal of the Society for Neuroscience* 22:546–553.

Borg, G. 1962. *Physical performance and perceived exertion*. Lund: C. W. K. Gleerup.

Botvinick, M., and D. C. Plaut. 2004. Doing without schema hierarchies: A recurrent connectionist approach to normal and impaired routine sequential action. *Psychol. Rev.* 111:395–429.

Botvinick, M. M. 2007. Multilevel structure in behaviour and in the brain: A model of Fuster's hierarchy. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 362:1615–1626.

Bruya, B. 2010. The rehabilitation of spontaneity: A new approach in the philosophy of action. *Philos. East West* 60 (2).

Bunge, S. A. 2004. How we use rules to select actions: A review of evidence from cognitive neuroscience. *Cogn. Affect. Behav. Neurosci.* 4:564–579.

Cahn, B. R., and J. Polich. 2006. Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychol. Bull.* 132:180–211.

Costanzo, P. 2002. Social exchange and the developing syntax of moral orientation. In *Social exchange in development*, ed. B. Laursen and W. G. Graziano. San Francisco: Jossey-Bass, 41–52.

Csikszentmihalyi, M. 1975. *Beyond boredom and anxiety*. 1st ed. San Francisco: Jossey-Bass.

Csikszentmihalyi, M. 1978. Attention and the holistic approach to behavior. In *The stream of consciousness*, ed. K. S. Pope and J. L. Singer. New York: Plenum, 335–358.

Csikszentmihalyi, M., and I. S. Csikszentmihalyi. 1988. *Optimal experience: Psychological studies of flow in consciousness*. Cambridge: Cambridge University Press.

Damasio, A. R. 1996. The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 351:1413–1420.

Damasio, A. R. 1994. *Descartes' error: Emotion, reason, and the human brain*. New York: Putnam.

Davidson, R. J., J. Kabat-Zinn, J. Schumacher, M. Rosenkranz, D. Muller, S. Santorelli, F. Urbanowski, A. Harrington , K. Bonus , and J. F. Sheridan. 2003. Alterations in brain and immune function produced by mindfulness meditation. *Psychosom. Med.* 65:564–570.

Dehaene, S., M. Kerszberg, and J. Changeux. 2001. A neuronal model of a global workspace in effortful cognitive tasks. In *Cajal and consciousness: Scientific approaches to consciousness on the centennial of Ramón y Cajal's Textura*, ed. P. C. Marijuán. New York: New York Academy of Sciences, 152–165.

Dehaene, S., and J. P. Changeux. 2005. Ongoing spontaneous activity controls access to consciousness: A neuronal model for inattentional blindness. *PLoS Biol.* 3:e141.

Dewey, J. 1896. The reflex arc concept in psychology. *Psychol. Rev.* 3:357–370.

Diedrichsen, J., T. Verstynen, A. Hon, S. L. Lehman, and R. B. Ivry. 2003. Anticipatory adjustments in the unloading task: Is an efference copy necessary for learning? *Experimental Brain Research. Experimentelle Hirnforschung. Experimentation Cerebrale* 148:272–276.

Diedrichsen, J., T. D. Verstynen, A. Hon, Y. Zhang, and R. B. Ivry. 2007. Illusions of force perception: The role of sensori-motor predictions, visual information, and motor errors. *J. Neurophysiol.* 97:3305–3313.

Dietrich, A. 2004. Neurocognitive mechanisms underlying the experience of flow. *Consciousness and Cognition: An International Journal* 13:746–761.

Dobrynin, N. 1966. *Basic problems of the psychology of attention: Psychological science in the USSR*. Washington, DC: U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, 274–291.

Dukas, R. 2002. Behavioural and ecological consequences of limited attention. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 357:1539–1547.

Ericsson, K. A., and A. C. Lehmann. 1996. Expert and exceptional performance: Evidence of maximal adaptation to task constraints. *Annu. Rev. Psychol.* 47:273–305.

Freeman, W. J. 1999. Consciousness, intentionality and causality. *J. Conscious. Stud.* 6 (11–12): 143–172.

Freeman, W. J. 2000. *How brains make up their minds*. New York: Columbia University Press.

Freeman, W. J. 2004a. Origin, structure, and role of background EEG activity: I. Analytic amplitude. *Clin. Neurophysiol.: Official Journal of the International Federation of Clinical Neurophysiology* 115:2077–2088.

Freeman, W. J. 2004b. Origin, structure, and role of background EEG activity: II. Analytic phase. *Clin. Neurophysiol.: Official Journal of the International Federation of Clinical Neurophysiology* 115:2089–2107.

Freeman, W. J. 2005. Origin, structure, and role of background EEG activity: III. Neural frame classification. *Clin. Neurophysiol.: Official Journal of the International Federation of Clinical Neurophysiology* 116:1118–1129.

Freeman, W. J. 2006. Origin, structure, and role of background EEG activity: IV. Neural frame simulation. *Clin. Neurophysiol.: Official Journal of the International Federation of Clinical Neurophysiology* 117:572–589.

Fuster, J. M. 2003. *Cortex and mind: Unifying cognition*. New York: Oxford University Press.

Gailliot, M. T., R. F. Baumeister, C. N. DeWall, J. K. Maner, E. A. Plant, D. M. Tice, L. E. Brewer, and B. J. Schmeichel. 2007. Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor. *J. Pers. Soc. Psychol.* 92:325–336.

Gibson, J. J. 1979. *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Greene, J. D., Nystrom, L. E., Engell, A. D., Darley, J. M., and Cohen, J. 2004. The neural basis of cognitive conflict and control in moral judgment. *Neuron* 44:389–400.

Grier, R. A., J. S. Warm, W. N. Dember, G. Matthews, T. L. Galinsky, J. L. Szalma, et al. 2003. The vigilance decrement reflects limitations in effortful attention, not mindlessness. *Hum. Factors* 45:349–359.

Grout, J., and S. Perrin. 2004. *Mind games: Inspirational lessons from the world's biggest sports stars*. Chichester, UK: Capstone.

Hektner, J. M., J. A. Schmidt, and M. Csikszentmihalyi. 2007. *Experience sampling method: Measuring the quality of everyday life*. Thousand Oaks, CA: Sage.

Hommel, B., J. Müsseler, G. Aschersleben, and W. Prinz. 2001. The theory of event coding (TEC): A framework for perception and action planning. *Behav. Brain Sci.* 24:849–878.

Hommel, B. 2007. Consciousness and control: Not identical twins. *Consciousness Studies* 14 (1–2):155–176.

Hurley, S. L. 2005. Bypassing conscious control: Media violence, unconscious imitation, and freedom of speech. In *Does consciousness cause behavior? An investigation of the nature of volition*, ed. S. Pockett, W. Banks, and S. Gallagher. Cambridge: MIT Press, 301–338.

Hurley, S. L., and N. Chater. 2005. *Perspectives on imitation: From neuroscience to social science*. Cambridge: MIT Press.

Inzlicht, M. 2006. Stigma as ego depletion: How being the target of prejudice affects self-control. *Psychol. Sci.* 17:262–269.

Ivry, R. 1997. Cerebellar timing systems. *Int. Rev. Neurobiol.* 41:555–573.

Ivry, R. B., and L. Helmuth. 2003. Representations of neural mechanisms of sequential movements. In *Taking action: Cognitive neuroscience perspectives on intentional acts*, ed. S. H. Johnson-Frey. Cambridge: MIT Press, 221–257.

Ivry, R. B., and T. C. Richardson. 2002. Temporal control and coordination: The multiple timer model. *Brain Cogn.* 48:117–132.

Ivry, R. B., and R. M. Spencer. 2004a. Evaluating the role of the cerebellum in temporal processing: Beware of the null hypothesis. *Brain: A Journal of Neurology* 127(Pt 8), E13.

Ivry, R. B., and R. M. Spencer. 2004b. The neural representation of time. *Curr. Opin. Neurobiol.* 14:225–232.

Ivry, R. B., R. M. Spencer, H. N. Zelaznik, and J. Diedrichsen. 2002. The cerebellum and event timing. *Ann. N. Y. Acad. Sci.* 978:302–317.

Jackson, S. A., and M. Csikszentmihalyi. 1999. *Flow in sports*. Champaign, IL: Human Kinetics.

Jacob, P., and M. Jeannerod. 2003. *Ways of seeing: The scope and limits of visual cognition*. New York: Oxford University Press.

Sigman, M., and S. Dehaene. 2005. Parsing a cognitive task: A characterization of the mind's bottleneck. *PLoS Biol.* 3:e37.

Slingerland, E. G. 2003. *Effortless action: Wu-wei as conceptual metaphor and spiritual ideal in early China*. Oxford: Oxford University Press.

Smit, A. S., P. Eling, M. T. Hopman, and A. Coenen. 2005. Mental and physical effort affect vigilance differently. *Int. J. Psychophysiol.* 57:211–217.

Spencer, R. M., R. B. Ivry, and H. N. Zelaznik. 2005. Role of the cerebellum in movements: Control of timing or movement transitions? *Experimental Brain Research. Experimentelle Hirnforschung. Experimentation Cerebrale* 161:383–396.

Tomlin, D., M. A. Kayali, B. King-Casas, C. Anen, C. F. Camerer, S. R. Quartz, et al. 2006. Agent-specific responses in the cingulate cortex during economic exchanges. *Science* 312:1047–1050.

Vohs, K. D., and R. F. Baumeister. 2004. Ego depletion, self-control, and choice. In *Handbook of experimental existential psychology*, ed. J. Greenberg, S. L. Koole, and T. Pyszczynski. New York: Guilford, 398–410.

Wallace, B. A. 2003. *Buddhism and science: Breaking new ground*. New York: Columbia University Press.

Wallace, B. A. 2007. *Contemplative science: Where Buddhism and neuroscience converge*. New York: Columbia University Press.

Wallace, B. A., and Z. Houshmand. 1992. *A passage from solitude: Training the mind in a life embracing the world: A modern commentary on Tibetan Buddhist mind training*. Ithaca, NY: Snow Lion.

Wallace, B. A., and Z. Houshmand. 1999. *Boundless heart: The four immeasurables*. Ithaca, NY: Snow Lion.

Wallace, B. A., and Tsoçn-kha-pa Blo-bzaçn-grags-pa. 2005. *Balancing the mind: A Tibetan Buddhist approach to refining attention* [formerly titled *Bridge of quiescence*]. Ithaca, NY: Snow Lion.

Wulf, G. 2001. Directing attention to movement effects enhances learning: A review. *Psychon. Bull. Rev.* 8:648–660.

1 Effortful Attention Control

Brandon J. Schmeichel and Roy F. Baumeister

"Pay attention!"

This familiar directive reveals an important clue about attention: Sometimes it exacts a cost. But under what conditions is attention costly? And what currency is spent when a person "pays attention"? In this chapter, we review evidence that the effortful control of attention exacts a psychological cost that is paid by a temporary reduction in the capacity for self-control.

External and Internal Determinants of the Focus of Attention

Attention has two masters. Its first and most formidable master is the external world, or the environment that stimulates the senses to form the bricks and mortar of conscious awareness. (Note that "external" does not refer only to stimuli outside the person. Physical sensations and emotional states, for example, have an experiential quality that resides inside the person but nonetheless may become an object of attention much like other, external stimuli.) Loud noises, pungent odors, and beautiful strangers all have the power to attract attention quickly and effortlessly. The list of stimuli that capture attention can be expanded to include a whole host of biologically relevant objects and events that have populated the environment throughout human evolutionary history. Snakes, fire, and lightning are on the list, and so are infants' cries, moans of pleasure, and novel aromas. In fact, novel stimuli of all kinds capture attention (e.g., Shiffrin and Schneider 1977). People pay attention to these stimuli literally without trying, without expending effort. When detected by the senses, such stimuli grab attention and quickly earn a preferential place in conscious awareness. This is true even when attention is intently focused on something else. For example, consider a motorist navigating an automobile down a busy highway. Although attending to the road ahead and anticipating one's next driving maneuver is challenging enough to fully occupy attentional resources, a salient external stimulus such as a collision off to the side of the road is likely to warrant at least a glance in the direction of the collision.

The directive to "pay attention" does not refer to these fast, automatic forms of attending, except perhaps in a metaphorical sense, as if the collision were to say "You had better pay attention to me!" A person does not need to be told to pay attention to a stimulus that captures attention quickly and effortlessly. Rather, admonitions to pay attention are necessary in precisely the opposite circumstance, in which attention is diverted away from a task or event by a stimulus that captures attention. If a driver is attending to the remains of a collision off to the side of a busy and unfamiliar road, for example, the passengers in the car are likely to demand that the driver pay attention to the road! It is in these circumstances—the ones in which the person must train attention away from attention-grabbing stimuli and toward other tasks or events—that "paying attention" is necessary. We suggest that moving attention away from attention-grabbing events exacts a psychological cost because this entails the self-control of attention.

The second master of attention, then, is the person who does the attending. Whereas the external environment may capture attention and thereby determine where attention is placed, the person may intentionally shift attention or maintain focus elsewhere. We are not the first to make this distinction, of course (cf. Norman and Shallice 1986). Several theorists distinguish between bottom–up versus top–down influences on attention, meaning, respectively, those that filter up from the senses to influence conscious awareness versus those that filter down from the person's intentions and goals (e.g., Desimone and Duncan 1995). That distinction corresponds to our external versus internal distinction. Other theorists contrast exogenous control versus endogenous control of attention (e.g., Jonides 1981), which also relates to the external–internal distinction we have made.

It is important to note that not all internal (top–down, endogenous) determinants of the focus of attention are expected to exact a psychological cost. For example, a person's motivations and goals help to determine what stimuli will capture attention (e.g., Lang 1995), and these are properly considered internal determinants of the focus of attention. However, attending to what one is motivated to attend to while ignoring other stimuli typically does not require self-control.

We propose that attention control exacts a cost when it entails counteracting or resisting what one is compelled to do by internal (e.g., motivational) forces or by powerful external stimuli that automatically capture attention. In other words, attention must be controlled when the stimulus the person is attending to is a stimulus the person is not otherwise inclined to attend to. In such instances, paying attention may exact a cost because it requires self-control.

Self-Control, Attention Control, and Limited Resources

We define self-control as the capacity to override or alter one's predominant response tendencies. Self-control is commonly understood as resisting immediate gratifications for the sake of long-term gains or goals (e.g., Fujita, Trope, Liberman, and Levin-Sagi 2006; Metcalfe and Mischel 1999), but in our usage self-control refers more broadly to any instance in which a subdominant response is deliberately substituted for a dominant one.

Attention control is one form of self-control. Other forms include emotion regulation, behavioral inhibition, and impulse control. Some theorists have suggested that attention control is the single most important or influential form of self-control because it contributes to all the other forms (e.g., Baumeister, Heatherton, and Tice 1994). Attention control refers to efforts to override or alter one's predominant attentional focus or tendency. Researchers have identified at least three forms of attention control. *Selective attention* refers to the act of focusing attention on one subset of the environment while avoiding or ignoring other attention-grabbing aspects of the environment. As we described earlier, some stimuli capture attention effortlessly and automatically. To ignore such stimuli or to divert attention away from them requires selective attention. *Divided attention* is a second form of attention control. This refers to attending and responding to multiple streams of information simultaneously. Insofar as the dominant mode of attention is to follow one stream of information at a time, attention control is required to split attention between two or more information streams. A third form of attention control is *sustained attention*, which refers to focusing attention on a stimulus or activity for an extended period of time. Generally speaking, novel stimuli capture attention. To sustain attention on the same well-worn stimulus or activity, then, requires an element of effortful persistence and attention control.

The benefits of successful self-control are difficult to overstate. Research has indicated that success at self-control contributes to subjective well-being, satisfying interpersonal relationships, and high levels of academic achievement (Duckworth and Seligman 2005; Kelly and Conley 1987; Tangney, Baumeister, and Boone 2004). Success at self-control is also commonly associated with resisting temptation, breaking bad habits, and performing well under pressure. Conversely, failures of self-control are associated with intellectual underachievement, interpersonal conflict, irrepressible appetites or addictions, and many other adverse outcomes (see Baumeister and Vohs 2004).

The main thesis of this chapter is that attention control exacts a psychological cost, paid in the form of a temporary reduction in the capacity for self-control. This view was inspired by the strength model of self-control (Muraven and Baumeister 2000). According to the strength model, the capacity to override or alter one's predominant response tendencies (including attentional tendencies) operates like a limited inner resource or strength. The sufficiency of this strength for overriding responses is determined in part by the person's previous behavior. If the person has recently exercised self-control, then strength may be temporarily depleted and hence the capacity for further self-control may be diminished.

Support for the strength model has come from experiments assessing performance on consecutive self-control tasks. In one memorable experiment, for example, self-control was manipulated by instructing hungry participants to eat only radishes while faced with the tempting sight and smell of chocolate. Soon afterward, self-control was measured on an unrelated task that involved solving challenging and frustrating puzzles. Participants who had resisted the temptation to consume chocolate more quickly gave up trying to solve the puzzles, compared to other hungry participants who had been free to eat chocolate without restriction (Baumeister, Bratslavsky, Muraven, and Tice 1998). This experiment and several others have supported the strength model by finding that initial efforts at self-control temporarily impair subsequent volitional efforts, as though the initial efforts reduced the strength of the impulse-control mechanism (for a review, see Baumeister, Schmeichel, and Vohs 2007).

In our view, attention control is a form of self-control. Consequently, we expect that acts of attention control consume and deplete the limited resource or strength that underlies self-control. By the same token, acts of attention control should vary in effectiveness according to the state of this limited resource, such that success at attention control should be less likely following other, unrelated acts of self-control.

Attention Control Depletes Resources

We begin by reviewing evidence that effortful attention control causes a temporary reduction in self-control. The basic experimental strategy used to test this hypothesis is as follows. Participants are asked to perform one of two tasks at the start of the experiment. One task requires attention control and the other one does not; otherwise the tasks are alike. Later in the experiment, all participants perform a test of self-control. Insofar as attention control exacts a cost that is paid with a reduction in self-control, participants who initially exercised attention control should perform worse on the self-control task later in the experiment, compared to participants who did not initially exercise attention control.

Because there is no single, gold-standard method to assess self-control, several different methods have been used to test the hypothesis that attention control causes a reduction in self-control. These range from tests of logical reasoning to assessments of the voluntary regulation of emotional expressions. By the same token, attention control is multifaceted, and so researchers have sought to manipulate the presence versus absence of attention control using different tasks. Before diving into the literature review, we will describe in detail the two main tasks that have been used to manipulate the presence versus absence of effortful attention control.

The first task, which we will call the *attention-control video task,* is adapted from an experiment by Gilbert, Krull, and Pelham (1988). For this task, participants watch a cognitive processing requires a degree of self-control to persist at problem solving when the correct answer is not immediately apparent. By contrast, success at the simpler cognitive tasks required less self-control and could be accomplished on the basis of automatic processes and well-practiced habits, such as those involved in encoding information into short-term memory. Thus, prior efforts at attention control undermined performance of complex cognitive tasks.

One complex cognitive process that is closely associated with self-control is thought suppression. A study by Gailliot, Schmeichel, and Baumeister (2006, study 3) tested the hypothesis that effortful attention control reduces the capacity to suppress thoughts and therefore increases the salience of thoughts related to death.

Research based on terror management theory suggests that people are motivated to keep thoughts of death out of conscious awareness (Arndt, Greenberg, Solomon, Pyszczynski, and Simon 1997; Greenberg, Pyszczynski, and Solomon 1986). One proximal or immediate response to being reminded about death is, therefore, to suppress or ignore death-related thought. Thought suppression requires self-control, however, so prior efforts to control attention may undermine the capacity to keep death-related thoughts out of awareness. Among individuals who have recently attempted to control attention, then, a reminder of death may cause an increase in death-related thought, even though this is precisely what they are motivated to avoid.

Gailliot and colleagues (2006) used the attention-control video task described previously. When the video had ended, all participants were shown a drawing and asked to list the first 10 thoughts that came to mind while looking at the drawing. The image in the drawing was ambiguous, such that it could be perceived either as two men sitting at a table enjoying a bottle of wine, or as a skull, with the head of the two men serving as the eye sockets and the table's legs serving as the teeth of the skull.

The prediction was that, compared to the absence of such efforts, prior efforts at attention control would cause participants to perseverate on the death-related content of the image (i.e., the skull). They did. Participants who had previously exercised attention control listed more death-related thoughts than did participants who had not previously exercised attention control. These results supported the idea that attention control has as a cost, a relative inability to keep unwanted thoughts from mind. In the case of this experiment, the specific cost of "paying attention" was an increase in thoughts associated with death.

Effortful attention control has also been linked to subsequent increases in racially biased responding. A study by Govorun and Payne (2006) manipulated initial efforts at attention control by having participants perform the Stroop task either for a brief period of time (approximately 1 minute) or for a longer period of time (approximately 15 minutes). After the Stroop task, participants completed an ostensibly unrelated study dealing with how people make quick decisions. More specifically, participants attempted to classify objects appearing on a screen as either guns or tools. Immediately prior to the appearance of each object, a face flashed on the screen for 200 milliseconds. Participants were instructed to treat the face as a warning signal that an object was about to appear on the screen. When the object appeared, participants were to respond as quickly as possible by pressing a key labeled either "gun" or "tool."

Some of the faces that flashed on the screen depicted white males and some depicted black males. Previous research had shown that people are more likely to identify harmless tools as guns when they are preceded by the face of a black man versus a white man. Hence, the faces served to prime racially biased responses. Govorun and Payne predicted that effortful attention control would reduce the capacity to control the influence of the primes on categorization behavior, and indeed it did. Automatic biases linking black males with weapons were more likely to guide behavior on the "quick decisions" task following a lengthy exertion of attention control. Following a much less taxing exertion of attention control, however, the automatic biases were controlled and hence served as less influential guides of behavior.

Prior efforts at attention control, therefore, appear to reduce the capacity to inhibit thoughts about death (Gailliot et al. 2006) and racially biased responses (Govorun and Payne 2006). Subsequent research sought to extend these findings by testing the more general hypothesis that initial efforts at attention control undermine subsequent efforts at attention control.

In one study by Schmeichel (2007), attention control was manipulated using the attention-control video task described previously. After watching the interview clip, participants completed a cognitive task that is commonly used to assess the capacity to control attention. This task, known as the Operation Span (OSPAN) task (Turner and Engle 1989), required participants to shift their attention between solving mathematical equations and encoding and recalling target words. For example, participants saw *Is* $(9 \times 3) - 1 = 2$*?* and had to indicate ("Yes" or "No") whether the given answer was correct. Then participants read a target word (e.g., *house*) for later recall. One target word was presented after each equation. Thus, participants read an equation, evaluated whether it was correct, read a target word, and then advanced to the next equation, the next target word, and so on. Participants saw two, three, four, or five equation–word pairings before being prompted to recall the target words in the set. Participants worked through 15 sets totaling 48 equation–word pairings in all.

If attention control operates like a limited resource, then performance on the OSPAN task should vary according to how participants watched the woman being interviewed during the first phase of the experiment. Participants who had controlled their attention to ignore words during the interview should perform worse than participants who did not have to ignore words while watching the interview. This is precisely what happened. Participants who had kept their attention focused on the interviewee while ignoring the words on the screen subsequently performed more poorly on a test of divided attention. More specifically, they were less successful at simultaneously encoding target words and solving mathematical equations. Hence, it appeared that one cost of paying attention (by focusing on the interviewee) is a reduction in the capacity to pay attention to two tasks simultaneously (storing words in memory while solving math problems). In other words, initial efforts at a selective attention task undermined subsequent efforts to divide attention. This pattern is consistent with the idea that effortful attention causes a temporary reduction in self-control, including the self-control of attention.

A follow-up experiment by Schmeichel (2007, experiment 3) indicated that attention control could undermine subsequent efforts to control emotional responses. Initial efforts at attention control were manipulated by having participants perform either a task that required them to encode and recall words (i.e., a simple short-term memory task) or a more challenging task that required them to encode and recall words while also solving mathematical equations (i.e., the OSPAN task described above). Although success at both tasks requires effort and attention, the working memory test required a great deal more attention control. After their respective tests, participants viewed an emotionally charged film clip under instructions to inhibit all outward expressions of emotional response. Participants' faces were videotaped and subsequently coded for visible expressions of emotion. The prediction was that, relative to participants who had performed a short-term maintenance task, those who had performed a working memory task would be less successful at inhibiting their emotional responses (i.e., they would express more emotion), as though the attention-control task temporarily depleted the capacity for emotion regulation.

Within this basic framework, this experiment also sought to address an alternate account of the predicted results, namely, that performing any effortful or difficult task reduces the capacity for self-control. According to this account, expending effort undermines subsequent self-control regardless of whether the initial effort was devoted to attention control. Schmeichel (2007) investigated this possibility by comparing the aftereffects of three different tasks that varied in difficulty. In one condition, participants performed a divided attention task that required them to coordinate performance on two tasks at once (i.e., the OSPAN task). In the other two conditions, participants performed tasks that required them to maintain information in short-term memory. The two short-term memory tasks differed in terms of difficulty, but neither of them required a great deal of attention control. If effort expenditure or the difficulty of a task is responsible for subsequent decrements in self-control, then performance on the emotion inhibition task should reveal a linear pattern such that inhibition is poorest after the divided attention task and best after the easy short-term memory task, with inhibition after the moderately difficult short-term memory task falling somewhere in between. If, however, only efforts at attention control reduce the capacity for self-control, then inhibition ability should be poorest after the divided attention task but equally good after the two short-term memory tasks.

To make the comparison between the aftereffects of effort expenditure versus attention control even more rigorous, the short-term memory tasks were made to last approximately six minutes longer than the divided attention task. If performing the divided attention task impairs response inhibition relative to performing the more time-consuming short-term memory tasks, then the conclusion that exerting attention control, rather than effort, is responsible for depleted self-control would be considerably strengthened.

The results convincingly supported the attention-control view. That is, participants who had completed the divided attention task were less successful at inhibiting emotional expressions during the subsequent video clip, compared to participants who had completed the short-term memory tests. Crucially, emotional expressivity did not differ between the two short-term memory groups: Those who had completed the difficult short-term memory task expressed just as little emotion as participants who had completed the easy short-term memory task. The two short-term memory tasks differed in difficulty (both according to participants' self-reports and according to participants' performance), so task difficulty was not responsible for the subsequent decrement in the self-control of emotional responses. The key distinction between the short-term memory tasks and the divided attention (i.e., OSPAN) task was the degree of attention control required. The task that required the most attention control had the most detrimental effect on the subsequent inhibition of emotional responding.

Interpersonal Consequences of Attention Control

Vohs and colleagues extended research on the aftereffects of attention control by considering the effects of attention control on interpersonal processes. They examined the extent to which the exercise of attention control made people prefer to engage in unlikable or maladaptive interpersonal styles. For example, one study by Vohs, Baumeister, and Ciarocco (2005, study 7) examined the effects of attention control on the preferred intimacy level of self-disclosure. Upon first meeting somebody or in the early stages of a relationship, a moderate level of intimacy in self-disclosure is often seen as likable because it indicates that one wants to increase the level of closeness in the relationship without overwhelming the other person with overly intimate details and without underwhelming the other person with impersonal trivia or an aloof attitude. Adaptive, likable interactions with a new acquaintance, then, often entail a moderate degree of self-disclosure.

People differ in how willing or comfortable they are in disclosing information about themselves, however. People with an avoidant attachment style are prone to avoid closeness. As a result, they tend to disclose relatively impersonal or nonintimate information about themselves to others, particularly under stressful conditions. People with an anxious–ambivalent attachment style, by contrast, are eager for closeness and therefore tend to disclosure intimate or personal information about themselves to others under stressful conditions.

Vohs and colleagues (2005) tested the hypothesis that initial efforts at attention control would undermine adaptive self-presentation and cause participants to migrate toward their predisposed desires for intimacy. They reasoned that efforts at attention control would cause avoidant individuals to become particularly impersonal or non-intimate in their preferred level of self-disclosure, whereas anxious–ambivalent individuals would prefer overly intimate or particularly personal self-presentations after an exercise in attention control. Put differently, the researchers anticipated that the cost of "paying attention" would be to bias self-presentations in a direction consistent with participants' characteristic attachment styles—and away from the most adaptive and likable degree of self-presentation (i.e., moderately intimate).

Participants first performed the Stroop task or a similar task that did not require attention control (name the color of Xs). Next, participants were provided with a list of topics from the Relationship Closeness Induction Task (RCIT; Sedikides, Campbell, Reeder, and Elliot 1998). The RCIT is typically used to create an increasingly intimate interaction between unacquainted individuals. The RCIT entails first asking and answering a series of nonintimate, low-disclosure questions, then progressing to moderate-disclosure questions, and, finally, higher disclosure questions. Vohs and colleagues (2005) presented participants with a list of questions from the RCIT in random order, such that low-, moderate-, and high-disclosure questions were intermixed throughout the list. Participants were asked to indicate how much they would like to discuss each topic. Because the topics on the RCIT list vary in intimacy (Sedikides et al. 1998), the researchers could quantify how willing (or unwilling) participants were to discuss intimate topics with a stranger.

As expected, exercising attention control at the start of the study caused participants to prefer levels of self-disclosure that veered away from adaptive, moderate levels of self-disclosure. Anxious–ambivalent individuals, who are prone to overly intimate self-disclosures, reported preferring more intimate self-disclosures after they had completed the attention-control task compared to the simpler, non-attention-control task. And participants with an avoidant attachment style preferred less intimate disclosures after the Stroop task versus the simpler, non-attention-control task.

These results indicated that the self-disclosure preferences of insecurely attached individuals were influenced by the prior exercise of attention control. In the absence of effortful attention control, however, all participants tended to favor moderately intimate self-disclosures—the kind that are typically the most pleasant and appropriate when interacting with a new acquaintance and that make the best impression.

Another study by Vohs and colleagues (2005, study 8) indicated that effortful attention control causes an increase in narcissistic self-descriptions (which, like inappropriate disclosures, tend to make bad impressions on interaction partners). Attention condition, participants simply read the words. In the attention-control condition, participants named the ink color in which the words were printed, and as is common in the Stroop color–word interference task, the words and the ink color mismatched. Participants in a third condition were also asked to name the ink color of a series of words, but these participants were further asked to form an implementation intention pertaining to the task. These participants were instructed to tell themselves: "As soon as I see the word I will ignore its meaning (for example, by concentrating on the second letter only) and I will name the color ink it is printed in."

Webb and Sheeran (2003) reasoned that the implementation intention could make otherwise effortful attention less effortful. Previous research had indicated that implementation intentions pass control of behavior from the self to anticipated environmental cues (Gollwitzer 1999). Thus, once the implementation intention is formed, the relevant behavior (e.g., naming the ink color) is elicited quickly and automatically by the relevant environmental cue (e.g., the word). If that is correct, then participants should be able to exercise effective attention control without experiencing a decline in subsequent performance.

After performing their respective color-naming tasks, all participants attempted to solve figure-tracing puzzles. As in the experiment by Wallace and Baumeister (2002), the puzzles were unsolvable and the main dependent variable was the duration for which participants persisted at trying to solve the puzzles. The results replicated the Wallace and Baumeister finding: Participants who performed the attention-control version of the color-naming task persisted less on the subsequent task than participants who performed the version of the task that did not require attention control. More important, the results indicated that the implementation intention eliminated the psychological cost of attention control: Participants who had formed implementation intentions to exercise attention control persisted just as long at the unsolvable puzzles as participants who had not previously exercised attention control. These findings suggest that making attention control more automatic, such as by forming specific intentions (how and when) to exercise attention control, helps to reduce the psychological cost of attention control.

Physiological Consequences of Attention Control

An ambitious series of studies by Gailliot and colleagues specified a physiological cost of attention control—reduced glucose in the bloodstream. Glucose is a vital fuel for the brain's functions. Gailliot and colleagues hypothesized that attention control (and self-control more generally) may be a particularly taxing brain function that draws on and consumes larger amounts of glucose than other, simpler mental operations.

In a first study linking attention control to glucose (Gailliot, Baumeister, et al. 2007, study 1), participants reported to a laboratory, and an experimenter assessed their baseline blood glucose levels with a blood sampling lancet. Blood glucose levels were measured (mg/dL) using an Accu-Chek compact meter. Next, the exercise of attention control was manipulated using the attention-control video task. After participants watched the video, the experimenter assessed blood glucose levels a second time.

Blood glucose levels were lower after participants had exercised attention control while watching a video—lower than their own levels before the video and lower than those of participants who had just watched the same video without controlling attention. These results provided the first evidence that attention control may be costly in a physiological sense, such that the exercise of attention control consumes large amounts of glucose.

A follow-up study (Gailliot, Baumeister, et al. 2007, study 3) tested the hypothesis that the drop in blood glucose following effortful attention control helps to explain some of the psychological costs of controlling attention. Once again, a baseline measure of blood glucose levels was collected, and then all participants watched a videotaped interview under instructions to ignore any words that might appear on the screen. (Note that all participants in this experiment were instructed to exercise attention control.) Following a second glucose measurement, participants completed the Stroop color-naming task, which is a popular measure of attention control. As described previously, the Stroop task requires the participant to override an incipient response (i.e., to read aloud the name of the word) in order to say instead the color in which the word is printed, and in that sense it requires participants to control their attention. The hypothesis was that lower blood glucose should impair Stroop performance in the sense of causing the person to take longer to get the right answer and in terms of making more errors along the way.

As predicted, lower glucose after having watched the video was associated with poorer Stroop performance. Specifically, the lower the person's glucose levels after exercising attention control, the more time it took to complete the Stroop task. Number of errors on the Stroop task showed a similar though nonsignificant pattern, such that lower glucose was associated with making more errors.

An additional study (Gailliot, Baumeister, et al. 2007, study 7) indicated that restoring glucose to the bloodstream eliminated the psychological cost of attention control. In this study, participants first completed 20 Stroop trials as a baseline measure of Stroop ability. They then were administered the attention–control video task, with half simply watching the videotaped interview and the other half being instructed to keep their attention focused on the woman and not on the words while watching it. After watching the tape, participants rated how often they had looked at the woman and the words, respectively. Next, participants were given 14 ounces of lemonade sweetened with either sugar (glucose condition) or a sugar substitute (placebo condition). Participants and the experimenter were blind to condition. Participants then completed filler questionnaires to allow time for the glucose from the drink (if they had any) to be metabolized. Last, participants completed 80 Stroop trials separated into four blocks. Speed and errors on the Stroop task constituted the dependent measures of self-control performance.

In the placebo condition, attention-control participants made more errors than watch normally participants. Once again, prior efforts at attention control undermined subsequent performance on the Stroop task (this time in terms of number of errors). This was not the case in the glucose condition, however. The glucose drink eliminated the tendency for initial efforts at attention control to impair Stroop performance. These results supported the hypothesis that glucose replenishes what has been depleted by effortful attention control and thereby attenuates the psychological costs of "paying attention."

Summary

The research reviewed in this section indicates that effortful attention control temporarily reduces the capacity for self-control. This psychological cost of paying attention was evident in impaired performance on tests of logical reasoning and reading comprehension, an increase in thoughts related to death, an increase in racially prejudiced responding, a reduced capacity to suppress emotional expressions, an increase in preferences to engage maladaptive self-presentational styles, increased narcissism, an increase in the price consumers were willing to pay for expensive products, reduced levels of glucose in the bloodstream, and reduced persistence at difficult challenges. These findings are consistent with the limited resource model of self-control insofar as acts of attention control appear to consume and deplete an inner resource required for further volitional efforts.

If attention control relies on the same limited resource as other forms of self-control, then acts of attention control should vary in effectiveness according to the state of this limited resource. More precisely, success at attention control should be less likely following other, unrelated acts of self-control. In the next section, we review the evidence pertaining to this hypothesis.

Evidence That Self-Control Undermines Subsequent Acts of Attention Control

Here we review evidence that acts of self-control cause a temporary reduction in the operation of attention control. The basic experimental strategy used to test this hypothesis is as follows. Participants are asked to perform one of two tasks at the start of the experiment. One task requires self-control and the other one does not; otherwise the tasks are alike. Later in the experiment, all participants perform a test of attention control. Insofar as self-control and attention control rely on the same underlying resource, then participants who initially exercised self-control should perform worse on the attention-control task later in the experiment, compared to participants who did not initially exercise self-control.

Important evidence that acts of self-control may undermine subsequent efforts to control attention was reported by Richeson and Shelton (2003). They found that racial interactions may undermine efforts at attention control. In one study white participants engaged in an interaction with either a black person (interracial interaction) or a white person (same-race interaction). After the interaction, all participants completed the Stroop color-naming task. The results indicated that performance on the Stroop task was undermined by a prior interracial interaction, particularly among participants who harbored relatively higher levels of racial bias. The authors argued that, compared to relatively nonbiased participants, white participants who harbored higher levels of racial bias would have to exercise self-control during an interracial interaction. Indeed, the evidence suggested that efforts to inhibit racial bias during the interaction were responsible for subsequent impairments in attention control on the Stroop task.

The findings reported by Richeson and Shelton (2003) represent the converse of the results reported later by Govorun and Payne (2006). Whereas Govorun and Payne found that performing the Stroop task undermined efforts to inhibit racially biased responding subsequently, Richeson and Shelton observed that efforts to inhibit racial bias led to poorer performance on the Stroop task subsequently. In tandem, these results strongly suggest a connection between attention control (as required by the Stroop color-naming task) and the self-control of racially biased behaviors, and they lend support to the view that attention control and other forms of self-control draw upon the same underlying resource or energy.

An experiment by Gailliot et al. (2006, study 7) found that inhibiting unwanted thoughts undermines subsequent efforts at attention control. Upon being reminded of the inevitability of their own personal death, people often attempt to suppress thoughts of death from conscious awareness (Arndt et al. 1997). Thought suppression depletes the limited resource for self-control, so a reminder of death should undermine the capacity to control attention. Gailliot and colleagues tested this hypothesis by prompting participants to ponder their own inevitable death or to ponder an aversive topic that was unrelated to death. A short time later, all participants attempted the Stroop color-naming task. On some trials, the meaning of words was mismatched with the ink color in which the words were printed, and so naming the ink color required participants to exercise attention control. On other trials, the words' meaning and ink color were matched, so that naming the ink color did not require attention control.

As predicted, participants who had pondered their own death performed worse than participants who had pondered a topic that was unrelated to death, but only on trials that required attention control (i.e., mismatched or incongruent color-naming trials). Performance on the congruent trials was unaffected by the manipulation of mortality salience. These findings supported the view that efforts to suppress troubling thoughts of death temporarily undermine the capacity to control attention.

The experiments reviewed thus far share some common elements. They all used a form of response inhibition as the initial self-control task, and they measured subsequent attention-control performance using the Stroop color-naming task. To provide converging evidence for the view that acts of self-control temporarily undermine subsequent efforts at attention control, Schmeichel (2007, experiment 4) used an initial self-control task that required response exaggeration (not inhibition) and a different dependent measure of attention-control capacity.

The experiment by Schmeichel (2007) revealed that emotion regulation undermines subsequent performance on a divided attention task. Participants in this experiment viewed two distressing film clips—one that depicted an eye surgery and one that depicted children discussing tragedies that had befallen their families. Participants were instructed to view the film clips in one of two randomly assigned ways. One group was instructed to exaggerate their emotional response to the film clips, whereas the other group was instructed simply to view the film clips. Subsequently, all participants attempted the OSPAN task, a widely used and well-validated measure of the capacity to control attention. The prediction was that exaggerating emotional responses would deplete the capacity for attention control and so disrupt performance on the OSPAN task. It did. Exaggerators scored significantly worse than other participants, consistent with the notion that prior efforts at emotion regulation have a negative impact on attention control. These results also suggested that efforts at emotion regulation had a greater impact on attention control than did negative mood. Participants in the two groups reported experiencing equally negative mood states in response to the film clips, so it appeared that attention control was impaired by prior efforts to regulate emotional responses above and beyond any effect of negative mood that stemmed from watching the distressing film clips.

Summary

The research reviewed in this section indicates that acts of self-control undermine subsequent efforts to control attention. Performance on tests of attention-control capacity was undermined by prior acts of inhibiting racial bias, inhibiting thoughts of death, and exaggerating emotional expressions. Furthermore, attention-control capacity was measured in two different ways, including the Stroop color-naming task and the OSPAN task. These findings are consistent with the limited resource model of self-control insofar as diverse acts of self-control appear to consume and deplete an inner resource required for subsequent attention control.

Implications and Conclusions

The findings we have reviewed indicate that control of attention draws on the same resources as needed for other acts of self-control. We saw that controlling attention

Lang, P. J. 1995. The emotion probe: Studies of motivation and attention. *Am. Psychol.* 50:372–385.

Metcalfe, J., and W. Mischel. 1999. A hot/cool-system analysis of delay of gratification: Dynamics of willpower. *Psychol. Rev.* 106:3–19.

Muraven, M., and R. F. Baumeister. 2000. Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychol. Bull.* 126:247–259.

Norman, D. A., and T. Shallice. 1986. Attention to action: Willed and automatic control of behavior. In *Consciousness and self regulation*, ed. R. J. Davidson, G. E. Schwartz, and D. Shapiro. New York: Plenum, 1–17.

Raskin, R., and H. Terry. 1988. A principal-components analysis of the Narcissistic Personality Inventory and further evidence of its construct validity. *J. Pers. Soc. Psychol.* 54:890–902.

Richeson, J. A., and J. N. Shelton. 2003. When prejudice does not pay: Effects of interracial contact on executive function. *Psychol. Sci.* 14:287–290.

Schmeichel, B. J. 2007. Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *J. Exp. Psychol. Gen.* 136:241–255.

Schmeichel, B. J., K. D. Vohs, and R. F. Baumeister. 2003. Ego depletion and intelligent performance: Role of the self in logical reasoning and other information processing. *J. Pers. Soc. Psychol.* 85:33–46.

Sedikides, C., W. K. Campbell, G. Reeder, and A. J. Elliot. 1998. The self-serving bias in relational context. *J. Pers. Soc. Psychol.* 74:378–386.

Schneider, W., and R. M. Shiffrin. 1977. Controlled and automatic human information processing: I. Detection, search, and attention. *Psychol. Rev.* 84:1–66.

Stroop, J. R. 1935. Studies of interference in serial verbal reactions. *J. Exp. Psychol.* 18:643–662.

Tangney, J. P., R. F. Baumeister, and A. L. Boone. 2004. High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *J. Pers.* 72:271–324.

Turner, M. L., and R. W. Engle. 1989. Is working memory capacity task dependent? *J. Mem. Lang.* 28:127–154.

Vohs, K. D., R. F. Baumeister, and N. J. Ciarocco. 2005. Self-regulation and self-presentation: Regulatory resource depletion impairs impression management and effortful self-presentation depletes regulatory resources. *J. Pers. Soc. Psychol.* 88:632–657.

Vohs, K. D., and R. J. Faber. 2007. Spent resources: Self-regulatory resource availability affects impulse buying. *J. Consum. Res.* 33:537–547.

Wallace, H. M., and R. F. Baumeister. 2002. The effects of success versus failure feedback on further self-control. *Self. Ident.* 1:35–41.

Webb, T. L., and P. Sheeran. 2003. Can implementation intentions help to overcome ego-depletion? *J. Exp. Soc. Psychol.* 39:279–286.

2 The Benefits and Perils of Attentional Control

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Executive attention is involved in the learning and performance of an array of complex cognitive and motor skills, ranging from reading comprehension (Turner and Engle 1989) to mathematical problem solving (Beilock, Kulp, Holt, and Carr 2004) to learning a new sports skill (Beilock, Carr, MacMahon, and Starkes 2002). Although investigations of the link between executive attention and behavior have spanned diverse areas of psychological science, most of this work has yielded surprisingly similar conclusions regarding the role of this cognitive construct in high-level performance—the more attentional resources one is able to devote to performance at a given time, the higher one's success rate will be on the types of learning, problem solving, and comprehension tasks encountered in both the confines of the laboratory and the complexity of the real world (Engle 2002).

Executive attention allows memory representations to be maintained in a highly active state in the face of distraction (Conway et al. 2005) and is a key component of the working-memory system. By pairing domain-general executive attention resources with domain-specific (e.g., verbal and visual) short-term storage and processing resources, *working memory* functions to control, regulate, and actively maintain a limited amount of information with immediate relevance to the task at hand (Miyake and Shah 1999).

Working memory is thought to be "so central to human cognition that it is hard to find activities where it is not involved" (Ericsson and Delaney 1999, 259). In support of this idea, numerous studies have shown a positive relation between an individual's working-memory capacity and performance on an array of complex cognitive activities (Conway et al. 2005). And one's executive attention ability—the ability to attend to the most important information, while inhibiting irrelevant information—has been shown to drive this relation between individual differences in working memory and performance (Conway et al. 2005; Engle 2002; Kane, Bleckley, Conway, and Engle 2001; Kane and Engle 2000, 2003). For this reason, working-memory capacity is often conceptualized as executive attention (Engle 2002), and we do so in this chapter as well.

As mentioned above, working-memory capacity is positively related to higher level cognitive functions such as general intellectual ability, reasoning, and analytic skill and is touted as one of the most powerful predictive constructs in psychology (Conway et al. 2005). Despite its well-established utility, however, recent work suggests that increased attentional control can sometimes have a downside. In this chapter, we discuss research across a variety of tasks—problem solving, category learning, language learning, and correlation perception—to contrast the renowned benefits of attentional control with its potential pitfalls. In doing so, we demonstrate that *less* executive attention devoted to the planning and unfolding of performance is sometimes better than more.

Problem Solving

"A problem exists when a living organism has a goal but does not know how this goal is to be reached" (Duncker 1945, 2). Problem solving involves creating new knowledge in order to achieve a specific goal, not just extracting existing knowledge. As such, successful problem solving builds on other aspects of cognition, including perception, language, and working memory. When solving problems under normal conditions, individuals with higher working-memory capacity have an increased ability to maintain complex problem information in a transient store, while inhibiting ancillary information that might compete for attention. In contrast, individuals with less working-memory capacity are more apt to spread their attention superficially across multiple aspects of the performance environment rather than focusing intently on a subset of task information.

Support for the idea that individual differences in working memory capture variation in attentional control ability comes from an investigation of dichotic listening by Conway, Cowan, and Bunting (2001). These researchers asked individuals lower and higher in working memory to listen to a message in one ear and ignore a message in the other ear. In the irrelevant, to-be-ignored message, the participant's name was sometimes mentioned. Of interest was whether an individual noticed his or her name, despite being instructed to ignore the message in which his or her name was played. Conway et al. found that individuals lower in working-memory capacity were more likely to detect their name in the irrelevant message than were those higher in working memory.

This ability of higher working-memory individuals to selectively control attention, so that ancillary information is blocked out, is typically viewed as an aid to problem solving—facilitating a planned, deliberate memory search for problem solutions and supporting the online execution of a series of problem steps. In contrast, simultaneously attending to information both focal and disparate to the task at hand typically leads to suboptimal performance. However, this is not always the case. We begin by describing situations in which higher working memory is useful for problem solving and how performance suffers when this cognitive control capability is compromised. We then go on to demonstrate that performance on some types of problems actually benefits when one has less opportunity or less ability to exert attentional control.

In many problem-solving situations, the more working-memory capacity individuals bring to the table, the better they perform. As an example, Beilock and Carr (2005; see also Beilock and DeCaro 2007) asked individuals to complete a demanding mental arithmetic task called modular arithmetic and looked at their performance as a function of individual differences in working memory. Modular arithmetic involves judging the truth-value of equations such as "34 = 18 (mod 4)." Although there are several ways to solve modular arithmetic equations, Beilock and Carr taught their participants a problem-solving method that involves two key problem steps. First, the problem's middle number is subtracted from the first number (i.e., 34 – 18), and then this difference is divided by the last number (i.e., 16 ÷ 4). If the result is a whole number (here, 4), the statement is true. If not, the statement is false. As one can see, successful performance on this task requires the ability to allocate attentional resources to multiple problem steps and the ability to work with and manipulate this information in memory (e.g., holding 16 in mind while dividing it by 4).

Individual differences in working memory were measured using two common assessment tools: Operation Span (OSPAN; Turner and Engle 1989) and a modified Reading Span (RSPAN; Daneman and Carpenter 1980). In the OSPAN, individuals are asked to solve a series of arithmetic equations while remembering a list of unrelated words. Equation–word combinations are presented one at a time on the computer screen (e.g., "(3 × 4) – 2 = 8? CAT"), and individuals are asked to read the equation aloud and verify whether it is correct. Individuals then read the word aloud. At the end of a series of two to five of these strings, participants are asked to write down the series of words, in the correct order. The RSPAN follows the same general procedure, except instead of verifying equation accuracy and reading a word, individuals verify whether a sentence makes sense and then read a letter aloud for later recall (e.g., "On warm sunny afternoons, I like to walk in the park.? G"). Working-memory scores on these tasks consist of the total number of words/letters recalled from all series in which recall was 100% accurate. The ability to maintain this type of information (e.g., the words/letters) in the face of distraction (e.g., equation or sentence verification) is said to reflect executive attention, or working-memory capacity (Engle 2002).

What Beilock and Carr (2005) found was quite consistent with the idea that more working memory is better than less. The higher individuals' working memory, the more accurately they solved the modular arithmetic problems. Attention benefits performance on this type of multistep mental arithmetic task. Beilock and DeCaro (2007, experiment 1) have recently replicated this effect (see figure 2.1, top line) and also shed light on why these working-memory differences might occur. To do this, we memory in the first place, precisely because pressure-induced worries co-opt the very working-memory resources that higher capacity individuals normally use to showcase superior performance.

We have tested these ideas using the same modular arithmetic problems described above (Beilock and DeCaro 2007). After performing a set of practice problems during which individuals were merely instructed to perform as quickly and accurately as possible, participants were given a scenario intended to elicit commonly experienced pressures such as social evaluation, peer pressure, and a potential outcome-dependent reward. Specifically, individuals were told that if they could improve their problem-solving speed and accuracy by 20% relative to the first set of problems, they could earn a monetary reward. This reward, however, was said to be part of a "team effort," and both the participant and a "partner" needed to improve in order for both parties to receive the reward. The partner, however, was said to have already participated in the study and improved by the required amount, leaving the rewards for both participants dependent on the present individuals' performance. Individuals were also videotaped by an experimenter and informed that the footage would be examined by math teachers and students in order to examine how individuals learn this type of math skill. After hearing these stakes, participants completed the second set of math problems.

In line with the idea that our type of pressure situation compromises the attentional resources of those who typically rely on this capacity the most, individuals higher in working memory performed the modular arithmetic problems significantly worse under high-pressure compared to low-pressure tests. As shown in figure 2.1 (bottom line), under pressure the performance of higher working-memory individuals (right side of the graph) was at the same level as individuals lower in this capacity. The performance of those lower in working-memory capacity (left side of the graph) was not affected by pressure—their performance was equivalent in both high- and low-pressure testing environments.

Why might the performance of low working-memory individuals be so resilient to pressure's negative effects? And why might the performance of high-working-memory individuals fall under pressure? As mentioned previously, in normal situations individuals lower in working memory are less likely to solve the math problems with a complex algorithm. And when individuals were not using complex strategies, they used shortcuts that circumvent the heavy demand on attentional control. Under pressure, lower working-memory individuals were still able to use these shortcut strategies (see figure 2.2, bottom line), given that they are not attention-demanding in the first place. This simpler problem-solving approach allows individuals to maintain adequate, above-chance (but less-than-perfect) problem-solving accuracy (see figure 2.1). As shown in figure 2.2, higher working-memory individuals under high pressure also adopted the problem-solving shortcuts used by their lower capacity counterparts. Pressure limited high-working-memory individuals' ability to use the intensive problem-solving approach. When working memory was compromised by environmental demands, those who typically perform at the top (i.e., higher working-memory individuals) showed the largest performance decline (see also Kane et al. 2001; Kane and Engle 2002; Rosen and Engle 1997). Here again, we see the necessity of executive attention resources for problem solving—when these resources are taken away by environmental distractions, performance falters relative to where one was under normal, low-stakes conditions.

As we saw in Conway et al.'s (2001) dichotic listening study, where lower working-memory individuals were more likely to notice their name in the message they were supposed to be ignoring than their higher working-memory counterparts, instead of focusing intently on a subset of task information, individuals with lower working-memory capacity are more apt to spread their attention superficially across multiple aspects of the performance environment (Conway et al. 2001). For these individuals, learning and skill execution may be more associative in nature, less dependent on controlled effort, and rely more on shortcuts or heuristics. Of course, attending to information both focal and disparate to the task at hand typically leads to suboptimal performance, such as when performing modular arithmetic problems requiring attention to multiple task steps. However, a diffuse attentional focus may not always prove harmful. Having less ability to maintain complex information in the focus of attention may, in some situations, lead to more inventive problem-solving approaches than would be discovered if attention were more stringently controlled.

Beilock and DeCaro (2007, experiment 2) examined this idea by asking individuals to complete a series of water jug problems (Luchins 1942). In this task, three jugs are shown on a computer screen, each able to hold a different maximum capacity and labeled as jugs A, B, and C (see figure 2.3). Individuals must use the capacity of these three jugs to derive a goal quantity of water. A mathematical formula is used to denote a solution, and importantly, individuals are instructed to use the simplest strategy possible, without the aid of pencil and paper. Six problems were used in total. The first three can only be solved with a complex algorithm (i.e., B – A – 2C). These complex problems require multiple problem steps (e.g., computing different subtraction operations while also maintaining the results of prior calculations in transient memory) and therefore rely heavily on attentional resources. Each of the last three problems, however, can be solved in two different ways: with the same complex algorithm as the first three problems or with a much simpler formula (i.e., A – C or A + C). The latter solution is more optimal in this case, because it is the simplest solution in terms of the number of steps involved. Notably, the formula given as a problem solution is directly reflective of one's problem-solving strategy. Of interest is whether these problem-solving strategies vary as a function of working-memory capacity—specifically whether individuals continue to use the more complex problem solution or whether they switch to the simpler, shortcut strategy when it is available.

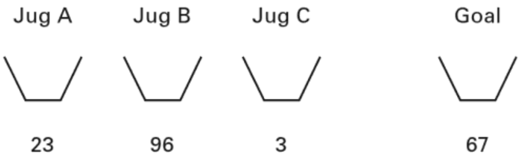

Figure 2.3
Water jug display. Participants derived a formula to obtain a “goal” quantity of water using jugs of various capacities. The first three problems were only solvable by the formula B – A – 2C (i.e., Fill jug B, pour out enough to fill jug A, then pour the remaining into jug C twice, leaving the goal quantity in jug B). The last three problems were solvable by this same difficult formula in addition to a much simpler formula (e.g., A – C). Individuals were informed that the water supply was unlimited and not all jugs had to be used.

We found that lower working-memory individuals were *more* likely to switch to the simpler solution when it became available. In contrast, individuals higher in working memory were more likely to persist in using the complex problem solution. Such persistence is known as *mental set* and, here, represents a negative artifact of previous experience in which individuals who are used to performing a task in a particular way tend to repeat this behavior in lieu of a more efficient strategy (Wiley 1998). Having a greater ability to execute multiple problem steps in memory seems to lead higher working-memory individuals to set in on a narrower problem-solving approach in line with their high capabilities. This is true even though, at the outset of the water jug task, we asked all subjects to solve the problems using the *simplest* strategy possible.

Such mental set effects can be especially pronounced when one is not only high in working memory but also has a lot of experience in a given domain. Ricks, Turley-Ames, and Wiley (2007) nicely demonstrated this phenomenon in the domain of baseball. They asked baseball experts and novices (as determined by a baseball knowledge test) to perform a creative problem-solving task called the Remote Associates Task (RAT; Mednick 1962). In this task, individuals view three words (e.g., “cadet, crawl, ship”) and are asked to discover a fourth word (i.e., “space”) that can be combined into a meaningful phrase with each of the three other words (i.e., “space cadet,” “crawlspace,” “spaceship”). The test words were either baseball neutral, having no obvious association with any aspect of baseball (as in the previous example), or baseball misleading. Baseball-misleading stimuli have one word that can be associated with baseball, but not in a way that would likely lead to a correct solution. For example, given the words “plate, broken, shot,” a baseball expert might quickly retrieve the word “home” as associated with “plate,” when the correct answer (i.e., glass) actually has no association with baseball at all.

To the extent that greater attentional control enables efficient retrieval and testing of multiple problem solutions, while inhibiting previously tested or ineffective solutions (Rosen and Engle 1997), one would expect higher working memory to be related to more successful performance on this problem-solving task. Indeed, for the neutral stimuli, the higher individuals' working memory, the better their solution accuracy (regardless of baseball expertise). A different pattern of results was seen for the baseball-misleading problems, however. First, expertise played a detrimental role. Baseball experts were outperformed by novices on the baseball-misleading problems. Experts have been shown to fixate on problem solutions that are activated by their extensive prior knowledge, leading to a negative mental set on this type of task (Wiley 1998). Moreover, the higher baseball experts' working memory, the worse they performed on the baseball-misleading problems. Working memory appears to have exacerbated the strategy rigidity commonly associated with expertise, by allowing hyperfocus on the incorrectly selected problem solution.

However it is triggered, whether from prior facility with a solution path or extensive knowledge of a particular domain, working memory supports a persistent approach in ways that are sometimes too selective. Such reliance on cognitive control not only may limit the discovery of new problem-solving approaches but may also lead to an attention-dependent learning strategy that overrides a more optimal associative strategy. We now turn to an example of the latter case in the category learning domain.

Category Learning

Similar to most problem-solving tasks, there are various ways one can go about learning the many categories that exist in our world. For example, individuals encountering new information, objects, or even people can explicitly test various hypotheses about the categories to which these belong. In order to learn to categorize objects in this way, individuals must form and test hypotheses about the potentially relevant features of the stimulus, move on to new hypotheses if current ones prove incorrect, and refrain from reexamining the hypotheses that have already been tested. This kind of complex process relies heavily on executive attention (Dougherty and Hunter 2003). However, there are other category learning strategies that are less attention-demanding, and in such cases, trying to devote executive attention resources to performance can actually result in a less-than-optimal learning situation.

When definitive rules can be applied to determine category membership, the best strategy is typically to hypothesize about the features that determine category membership. Tasks used to resemble this process in the lab are called *rule-based category learning* tasks (Ashby and Maddox 2005). Individuals usually see a series of categorization stimuli one at a time and are instructed to categorize each into category "A" or "B." Following each categorization choice, individuals usually receive feedback. The idea is that, over a series of categorization trials, individuals will learn to correctly categorize the stimuli to some criterion (e.g., eight correct categorization responses in a row; Waldron and Ashby 2001). A variety of categorization stimuli have been used for these tasks. For example, Waldron and Ashby (2001) created 16 stimuli, each a square with an embedded symbol in it. Each stimulus had four dimensions, with one of two levels of each dimension: square–background color (yellow or blue), embedded symbol shape (circle or square), symbol color (red or green), and number of embedded symbols (1 or 2). For a rule-based task, stimuli are correctly categorized based on an easily verbalizable rule regarding one of these features (e.g., "If the embedded symbol is a circle, choose category A; if the symbol is a square, choose category B"). The specific rule is established beforehand by the experimenter, and the individual discovers it over a series of learning trials.

Because generating and selecting different rules about category membership, while inhibiting previously selected features, relies extensively on working-memory resources (Ashby and O'Brien 2005), it is not surprising that individuals with more of this capacity outperform lower working-memory individuals on this type of rule-based learning task (see figure 2.4, left side; DeCaro, Thomas, and Beilock 2008). Moreover, when

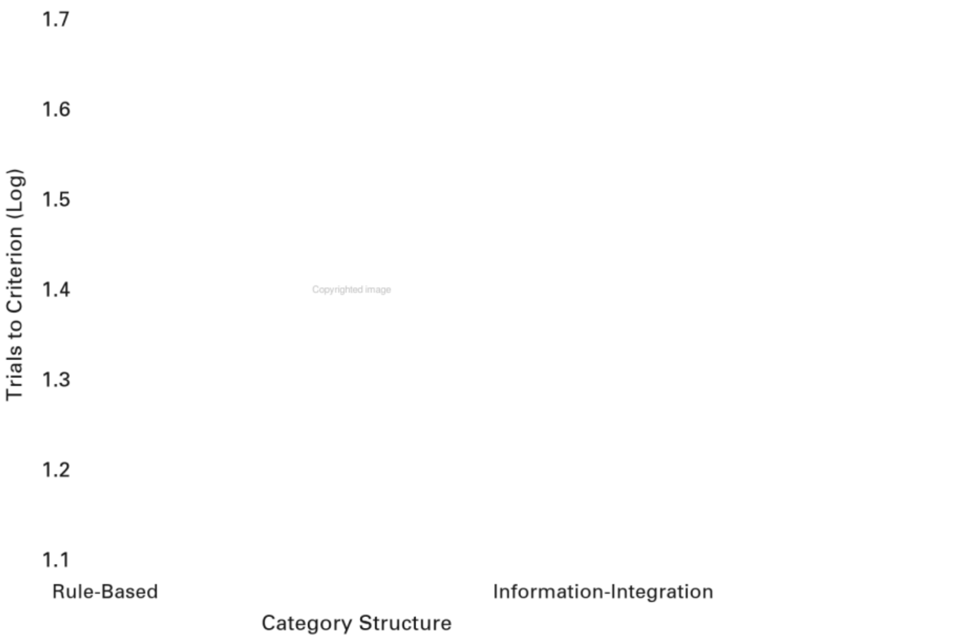

Figure 2.4
Mean number of trials taken to learn categories to a criterion of eight correct categorization responses in a row (log transformed), as a function of category structure and individual differences in working memory (WM). WM was measured as a continuous variable—nonstandardized regression coefficients are plotted at ±1 *SD*.
Adapted from DeCaro, Thomas, and Beilock 2008.

It should be noted that the exact role of executive attention in language learning has not yet been fully unpacked. Some use the term "working memory" (e.g., Kersten and Earles 2001), and others use terms like "maturational state" (Newport 1990). Moreover, Newport and others primarily describe the potential benefits of working-memory limitations in language learning in terms of the limited storage capacity to perceive and remember small segments of language, highlighting the short-term storage aspects of working memory more than the attentional control capabilities central to this construct. Yet, although the specific role of the executive attention component of working memory has not been central to this theory of language learning, this initial research does point to the potential negative impact of greater attentional control abilities and is consistent with research in similar domains such as information-integration category learning and, as will be seen below, correlation perception.

Correlation Perception

Research on the perception of correlation, or statistical regularities between two events, has also found an advantage of limited processing capacity. In one demonstration of this effect, Kareev, Lieberman, and Lev (1997) presented participants with a large bag containing 128 red and green envelopes and asked them to select one envelope at a time. Inside each envelope was a coin, marked with either an "X" or an "O." When selecting each envelope, individuals were asked to predict which marking would appear on the coin, based on the color of the envelope. If the prediction was correct, participants earned the coin in the envelope. Counterintuitively, individuals performing worse on a digit span task, a measure of short-term memory, rated the correlations between envelope color and coin marking more accurately than those performing well at the memory task. Kareev and colleagues explained that individuals with less cognitive capacity are more likely to perceive narrow "windows" of events out of an expansive experience with co-occurring events—that is, lower capacity individuals will perceive and remember only a small chunk of these trials. Smaller subsets of trials are more likely to be highly skewed, and therefore lower capacity individuals will perceive correlations as more extreme, facilitating performance on this type of task (for a debate of these findings, see Anderson et al. 2005; Cahan and Mor 2007; Juslin and Olsson 2005; Kareev 2005).

Gaissmaier, Schooler, and Rieskamp (2006) replicated Kareev and colleagues' key findings but offered an interpretation based on strategy differences between individuals lower and higher in cognitive resources. Specifically, high-span individuals are said to employ complex hypothesis testing such as *probability matching*, in which the next event to be predicted in a series is judged from the overall probability that the event has been shown to occur in the past. For example, if event "A" has occurred about