

Book review

Coffee with the executive

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*On Task: How Our Brain Gets Things Done*David Badre
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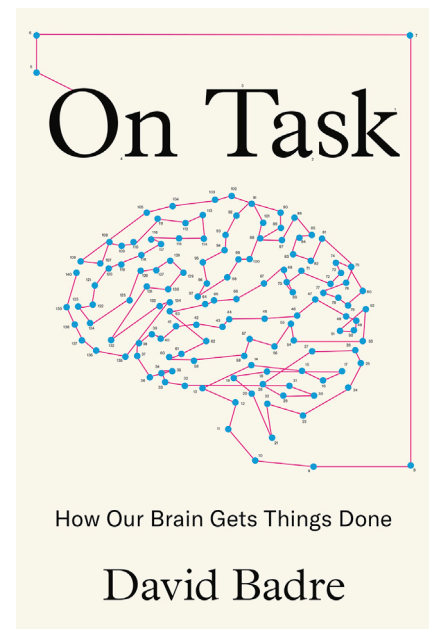
Making coffee features prominently in this excellent book on the cognitive neuroscience of executive functions (or, to use a more contemporary term, cognitive control). To make coffee, you require plans (going to the kitchen, making sure you have enough time), implemented into an organized sequence of actions (finding the coffee and filter, filling the carafe with water), all while not accidentally switching to a tea-making plan. David Badre uses the act of coffee making as his example of a seemingly simple everyday task to introduce core ideas, such as hierarchical control and chained processes.

Badre defines cognitive control as what lies in the gap between knowledge and action, the processes that turn “an abstract goal into the intricate, moment-to-moment sequencing of behavior”. Studies of neuropsychological patients with frontal lobe lesions illustrate the need to postulate this special mechanism. On the one hand, these patients are often able to think of plans and goals, and their knowledge of the rules of everyday life is reasonably intact. On the other hand, they often execute a series of inappropriate actions, without noticing the problem with the overall plan. Famous examples of these can be found in Lhermitte’s descriptions of his patients¹. One of them was invited to the professor’s house, and when he noticed a bed with the bedspread off and the top sheet folded back he proceeded to undress himself and get in the bed. Another patient, noticing a tongue depressor on Lhermitte’s table, went ahead and examined the professor’s throat.

From this starting point, Badre provides a thorough and engaging

introduction to the history of the study of cognitive control, and an overview of new developments from the last 20 years. At the core of these new developments is the corticostriatal model of working memory gating developed by O’Reilly and Frank² that underlies our ability to maintain a mental workspace as well as control what rules and content get in, and what gets pushed out. The key players in this mechanism are the frontoparietal multiple-demand network and the basal ganglia, shaped by reward-based learning. In the first few chapters we get a clear picture of how hierarchical task rules are implemented in the brain and how this circuitry allows us to stop an unwanted action or thought. The following chapters lay out how this mechanism of cognitive control connects with other processes, notably long-term memory and motivation.

Throughout the book, Badre moves effortlessly between findings in cognitive psychology, neurology, neuroimaging, and computational modeling approaches. The evolutionary framework that holds these strands together is first outlined in the opening chapter, which points to gradually more complex toolmaking as evidence for the emergence of cognitive control processes during the Upper Paleolithic era. Culture makes a brief appearance here as one of the factors that accelerated human evolution, but the account is clearly focused on processes in individual brains. Badre highlights one supremely important evolutionary insight, namely that our memory did not evolve for storing information, like lists of facts, but rather for preserving context-dependent episodic memories in order to make useful predictions for what to do next, i.e. *planning*. The chapter on memory retrieval lays out how the frontostriatal circuits of working memory gating are integrated with frontotemporal circuits, including the hippocampus, to achieve this goal. Though it may be too much to ask given the current state of cognitive control research, references to language and social cognition are by and large missing from this account. How did the emergence of a re-combinable symbol system interact with the development of a coding



system for complex and interleaved plans? As inherently social creatures, how do our motivations drive our planning? Only a few threads on our social brain are weaved in throughout the book.

Alongside presenting the state-of-the-art model of cognitive control, *On Task* offers some food for thought for a wider, non-specialist audience. It has clear and straightforward explanations for why we can’t multitask, why ego depletion isn’t real, and why you shouldn’t recommend memory-training apps to your elderly relatives (yet). The illustrations of some core concepts are fun and engaging, such as the story of Eugene O’Neill’s two desks. O’Neill, playwright of *The Iceman Cometh* and *Long Day’s Journey into Night*, often worked on two plays simultaneously. In his office he had two desks set up facing away from each other, with a different set of objects (lamps, memorabilia) on each as cues to keep the two creative tasks separate. Badre points out that the reason why we are struggling with task management in the age of laptops and cell phones is that it is the opposite of this setup: neither the virtual environment (the screen) nor the physical environment give us any external cues to whether we should be revising a manuscript, paying a parking ticket, or watching a funny cat video.

In each chapter, central ideas are traced back to classic figures

in the history of psychology and neuroscience, such as James, Freud, and Lashley. Badre skillfully weaves their stories into his explanations of complex topics, such as inhibition, retrieval, and mental effort. Female researchers and racially minoritized scientists, long ignored in textbooks, are represented here as well. For example, we are introduced to Margaret Floy Washburn, who in 1894 became the first woman to get a PhD in Psychology and later became the President of the American Psychological Association, and we get a glimpse of how her work influenced theories of hierarchical control. The section on Tsuruko Arai in the chapter on motivation is also memorable. Arai was the student of Thorndike at Columbia University and, in 1912, she was the first Japanese woman to get a PhD (in any field). Her most influential study, which she conducted on herself, was the first demonstration that mental effort cannot be depleted in the same way as physical effort — and is a story that can be used to put any graduate student's woes into perspective. She performed hard multiplication problems for 12 hours a day, for four days straight, taking only two- or three-second breaks between problems, all while continuously keeping track of her time in completing the problems and her subjective experiences. After accomplishing this extraordinary feat, despite feeling “a sort of mental nausea”, she never reached a state where she could not undertake another problem. Badre shows the direct line leading from Arai's pioneering work to our current mechanistic understanding of mental effort, a key component in the model of cognitive control described in his book.

While *On Task* does a thorough job of relating cognitive control to systems of long-term memory, motivation, and action, it does a bit of sleight of hand with the definition of cognitive control. We move back and forth between cognitive control in a narrow sense (as described above, implementing complex plans into hierarchical sequential actions, such as making coffee) and cognitive control in a broader sense (which includes devising abstract plans that may never end up in sequential actions). That is, at times it sounds as though cognitive

control includes much of what we generally consider as thinking (fluid intelligence), while at other times it does not. For example, when talking about individual differences, Badre mentions that he, as a prototypical absent-minded professor, often has trouble with cognitive control. But while he may turn on the coffee machine without water, coffee, or a filter, it is unlikely that he would write a journal article without an introduction, results, or a discussion. Then, in one of the final chapters, he asserts that gF — the fluid intelligence factor that has fascinated psychologists since the early days of intelligence testing — is closely tied with cognitive control. We can safely assume that Badre would score high on tests of gF. Drawing a clearer boundary between the narrow and broad meanings of cognitive control would be an important next to-do item for research on cognitive control.

This lack of commitment between the two definitions of cognitive control also contributes to another fuzzy conceptual boundary: it is not clear what constitutes *not* being on task. Spontaneous thoughts (called daydreaming or mind-wandering in the cognitive control literature, terms that sound mildly pejorative) are only discussed once, in the chapter on motivation, but even here the focus is on how they can be unpleasant and aversive (as if we only ever thought of our anxiety-provoking mental to-do lists). If we want to understand cognitive control in the broader sense, spontaneous thoughts in plan building need to get a better reputation. It would have been valuable to see this perspective, for example through the emerging neuroscientific research on mindfulness and curiosity.

The last chapter covers changes in cognitive control in children and the elderly. Badre emphasizes that the protracted development of the prefrontal cortex in humans does not mean that children cannot use cognitive control until they reach their early twenties (a view that he calls the Death Star model of development). His main point is that this long period is the price we pay for brains that are adaptable to diverse environments. But there is very little about what these different adaptations might be.

Will the differences be superficial (e.g. different sets of mental rules, such as the rules for weaving a complex geometric pattern versus those for playing Minecraft) or more substantial (differently organized systems, such as those able to spontaneously create hierarchical rules versus those limited to flat sequences)? There was a missed opportunity here to discuss research on environmental diversity: for example, the debate about the bilingual advantage in cognitive control in children or the effects of socioeconomic status on frontoparietal network development (a topic to which Badre himself has contributed³).

Despite these missed opportunities, Badre's integrative framework on cognitive control challenges researchers working in adjacent fields to rethink well-entrenched ideas: for example, the debate about the nature of visual working memory storage (whether to conceptualize memory as ‘all or nothing’ or allowing for a graded representation of items) that has raged on over the last 20 years. As of yet, little of this work is integrated with mechanisms of cognitive control: that is, how task rules and context dependency could be integrated with these models. Similarly, many developmental psychologists will find that they have to update their models of executive functions to be consistent with the one laid out in this book, for example by treating working memory as a more dynamic process that enables the implementation of plans.

As for me, I'm off to make some coffee. I need to figure out how to fit 17 desks in my office.

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