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The Neuroscience of Goals and Behavior Change

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Abstract

The ways that people set, pursue, and eventually succeed or fail in accomplishing their goals are central issues for consulting psychology. Goals and behavior change have long been the subject of empirical investigation in psychology, and have been adopted with enthusiasm by the cognitive and social neurosciences in the last few decades. Though relatively new, neuroscientific discoveries have substantially furthered the scientific understanding of goals and behavior change. This article reviews the emerging brain science on goals and behavior change, with particular emphasis on its relevance to consulting psychology. I begin by articulating a framework that parses behavior change into two dimensions, one motivational (the *will*) and the other cognitive (the *way*). A notable feature of complex behaviors is that they typically require both. Accordingly, I review neuroscience studies on cognitive factors, such as executive function, and motivational factors, such as reward learning and self-relevance, that contribute to goal attainment. Each section concludes with a summary of the practical lessons learned from neuroscience that are relevant to consulting psychology.

Keywords

Goal Striving; Behavior change; Habit formation; Neuroplasticity; Motivation

Setting goals is easy; achieving them is hard. Why? This question has long stumped humanity and will certainly not be answered in this article. A full explanation of why it is hard to accomplish a goal or change old habits may never be possible. However, all hope is not lost. Research at the interface of neuroscience and psychology has made significant strides in uncovering the machinery behind goal pursuit. This knowledge, in turn, provides clues about the various ways that behavior change can go wrong and how to improve it. In this article, I present a brain-based framework for understanding how goal pursuit works and how to facilitate behavior change. Along the way, I highlight specific and practical lessons learned that are relevant to the science and practice of consulting psychology.

Goals and the Four Types of Behavior

What do I mean by goals? Colloquially, a goal is any desired outcome that wouldn't otherwise happen without some kind of intervention. In other words, a goal is a detour from

the path of least resistance. Formally, a goal is a desired future state (an end) coupled with a set of antecedent acts that promote the attainment of that end state (means; see Kruglanski, Shah, Fishbach, Friedman, Chun, & Sleeth-Keppler, 2002 for a summary). I present the informal definition first because it captures something that is missing from the formal one: a sense of what people actually mean by the word “goals” and how we use them. Technically, according to the formal definition, going out with friends to celebrate someone’s birthday is goal; it is an imagined end state and one must deploy various means to make it happen. But most people wouldn’t think of planning to go to a party later tonight as a goal. In practice, we set goals in cases where we need to do something that hasn’t happened yet and isn’t likely to happen on its own.

The difference between the two definitions of goals highlights an important aspect of goals and the way it is often overlooked. Goals are usually things we *want* but *have difficulty achieving* even when we know they are achievable. Otherwise, we wouldn’t need a goal in the first place. That sense of struggle is also captured in the term *behavior change*, which I use interchangeably with goal pursuit here. It’s not engaging in behavior, per se, but rather *new* behavior that is hard. To pursue what most people call a goal involves doing something different than what has been done before. For example, a primary incentive underlying achievement motivation (i.e., the need for achievement) is to demonstrate one’s capability to perform well on a new or challenging task (McClelland, 1985).

To understand why new behavior is so hard, it’s useful to think about two dimensions that give rise to behaviors. The first dimension captures the skills, capacities, and knowledge required to engage in a behavior. This includes mapping out the steps to take and having the skill to execute an action, as well as related cognitive processes such as attentional focus, inhibitory control, and working memory capacity. Because it reflects the means used to achieve a goal, I refer to the first dimension as the *way*. The second dimension captures the desire for and importance of a behavior. This includes wanting to achieve a goal and prioritizing it over other goals, as well as related motivational processes such as volition, intention, and the nature and strength of the drive for achievement. Because it relates to the motivation to engage in a behavior, I refer to the second dimension as the *will*.

As shown in Figure 1, these two dimensions give rise to four broad types of action. *Complex-Routine* behavior, in the top-left quadrant, requires some level of skill or knowledge but little motivation. Habitual behaviors reside in this quadrant: they can be quite complex yet are often triggered by external cues without motivation. For example, many drivers have piloted their car somewhere familiar, such as a child’s school, without thinking and despite an intention to go elsewhere. Indeed, a hallmark of habitual behavior is engaging in it even (or especially) in the absence of a conscious goal to do so (Wood & Neal, 2007). *Simple-Routine* behavior, in the bottom-left quadrant, requires little skill and motivation. For example, walking, eating, and other behaviors related to primary rewards reside in this quadrant. These behaviors are so easy and effortless that we hardly think of them as goals at all. Because they are located in the same place on the horizontal axis and on different places on the vertical axis, the key difference between the first two types of behaviors is the level of skill they require. *Simple- novel* behavior, in the bottom-right quadrant, requires high motivation but low skill to accomplish. Simple but new (and at times unpleasant) tasks such

as changing a diaper belong in this quadrant. The most interesting kind of behavior is in the fourth quadrant: *Complex-Novel* behavior that requires high skill and high motivation. The goals that people care about most reside there.

Differences between adjacent quadrants within this space are instructive. The key distinction between a rote, unpleasant task (bottom-right) and a complex, hard one (top-right) is skill- and knowledge-oriented. Changing one diaper doesn't take much ability, but building a machine to do the task for you would require decades of schooling. Both require high levels of motivation. The lesson is that moving up and down in this space is a matter of skill-building. In contrast, the distinction between a complex task that happens easily (top-left) and one that requires effort (top-right) is motivational. Driving to your child's school is easy because you've done it so many times that it has become a matter of habit. In contrast, driving for the first time in a new country relies on the same skillset but feels much harder because it forces you to focus and apply the driving and navigation skills you already have. As you do it more it becomes easier, of course, but you can still do it on the first attempt as long as you try hard enough. Moving from left to right in this space, therefore, is a matter of effort more than one of skill or knowledge. Once a person possesses the capacity and knowledge to accomplish a difficult task, the missing piece is motivation.

Lessons learned for consulting psychology

In light of this framework, the first step to facilitating behavior change is to diagnose the source of the difficulty. Consultants and coaches can do foundational work with their clients early in the behavior change process to pinpoint the nature of the behavior change and identify how the new behavior is different from old patterns. The first step to helping a client with behavior change can involve answering these questions:

- Does the client already have the skills required for the new task?
- Is the barrier to change a lack of a way or a lack of a will?
- Is the person trying to move up, to the right, or both on the axes in Figure 1?

Once the most relevant dimension of change is identified, the second step is to drill down to learn more about the specific nature of the motivation or skills/capacities that will be the target. For example, consider the questions:

- If motivation, is the client lacking motivation to approach a desirable outcome or to avoid an undesirable one (e.g., Berkman & Lieberman, 2010)?
- If motivation, is the client generally unmotivated, or highly motivated to a different goal besides than the behavior change goal?
- If skills, are they related to interpersonal abilities (e.g., empathy and perspective taking) or executive functioning (e.g., inhibition and attentional control)?
- If skills, is it possible that the client already possesses the skills but is stuck in a closed mindset and overly focused on one aspect of the behavior, such that a broadening of perspective might open new avenues for progress using other skills?

The relevant neuroscience will be quite different depending on the answer to these questions. In the following sections, I summarize the neuroscientific literatures on the will and the way with an emphasis on practical lessons for consulting psychology.

The neuroscience of the “way”: Executive function and cognitive control

Research on “the way” of goals and behavior change has mostly focused on constructs such as attention, working memory, inhibitory control, and planning – collectively known as executive function. A great deal of knowledge has been gained from neuroscientific studies about executive function, mostly about the neural systems and circuits that implement executive function (sometimes referred to as the task-positive network; Fox et al., 2005), and also about how disruptions to those circuits can cause alternately specific or broad impairment depending on the precise location and nature of the damage (Alvarez & Emory, 2006; Stuss & Knight, 2012). Recent work has even begun to explore the bidirectional relationship between central and peripheral nervous system functioning in the context of goals, such as how activation of the sympathetic nervous system and hypothalamic-pituitary-adrenal axis during stress can influence executive function (Roos et al., 2017). Together, imaging and lesion studies have illuminated many of the mechanistic elements and processes involved in complex goal pursuit (Stuss, 2011). This information, in turn, contains some important lessons for consulting psychology about the capabilities and limits of executive function that are directly relevant to goals.

Despite substantial progress in knowledge of how executive function operate at the level of the brain, there is only sparse neuroscience research about how executive function might be improved. What little research there is suggests that executive function is more fixed than malleable by intervention, but there are some hints that targeted improvement might be possible. In this section, I review recent neuroscientific studies on executive function with respect to three questions that are pertinent to goals and behavior change: What is the nature of executive function? Is executive function a limited resource? And can executive function be improved with practice?

What is the nature of executive function?

Executive function refers to a suite of higher-level cognitive skills and capacities that generally promote successful human functioning. Attention, task switching, working memory, and inhibitory control are usually described as executive functions, though there is debate about the precise definition of the term (Banich, 2009). Executive function involves some degree of updating information, shifting focus between targets or mental sets, and inhibiting irrelevant or distracting information (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Rather than enter that debate, I will describe broad features of executive function that are shared across most definitions. These features are useful for providing clarity and context for the subsequent questions regarding the limits and improvability of executive functions.

Executive function has three characteristic features: it is *effortful*, operates *consciously*, and engaged in service of *novel goals* as opposed to rote or overlearned ones (e.g., Miyake & Friedman, 2012). Effortful means that they feel hard and must be completed serially. In fact,

emerging evidence suggests that one function of the dorsal anterior cingulate cortex (dACC; Figure 2), among several others, is to efficiently allocate cognitive resources by tracking the amount of mental work a task will require (Shenhav, Cohen, & Botvinick, 2016). For example, activity in the dACC scales with the upcoming demand for control and also the potential payoff of that control (Kouneiher, Charron, & Koechlin, 2009). It appears that the brain has dedicated regions not only to *executing* control but also *allocating* that control to various tasks.

Executive function is conscious, which means that it occurs within awareness and requires conscious attention. People know when they are engaging in executive function because it becomes the center of attention in a given moment. A classic example of executive function is mental math, such as multiplying 13 by 17. In contrast to things such as breathing or adding 1+1, you know when it happens because it occupies all of your attention, and it is generally voluntary. The steps involved in solving that problem recruit a host of executive functions surrounding attention: focusing attention on the appropriate column, swapping information in and out of attention, and restricting attention to the desired part of the operation to the exclusion of others. These short-term memory and attentional processes are supported by complex interactions among lateral prefrontal and parietal cortices including aspects of all three frontal gyri, the superior frontal sulcus and precentral gyrus, and the supramarginal gyrus and temporalparietal junction (Figure 2; Nee, Brown, Askren, Berman, Demiralp, Krawitz, & Jonides, 2012). The role of these regions is not just to maintain information, but also to disengage attention from irrelevant or previously-relevant information as appropriate to the task (Shipstead, Harrison, & Engle, 2016). The importance of *redirecting* attention underscores the limited-capacity nature of working memory and executive function more generally. Extensive cognitive processes and neural resources are dedicated to gating which information enjoys the focus of attention and which must be ignored. In this way, executive function generally, and attention specifically, play a key role in how open or closed we are to new ideas and perspectives during goal setting and goal striving.

In addition to feeling effortful and occupying conscious attention, a third characteristic property of executive function is that it specializes in novel tasks. It enables humans to do things that we've never done before. In fact, the basic role of the entire prefrontal cortex has been described broadly as coordinating behavior to achieve novel goals (Miller & Cohen, 2001). The ability of our prefrontal cortex to plan and execute novel behaviors is one of the defining characteristics of humans and one that sets us apart from nearly all other animals. However, this ability is not unlimited. In light of the limited capacity of attention and working memory, the prefrontal cortex has a second function that is nearly as critical: to learn to automate novel behaviors to the point that they no longer take up precious space in consciousness. Research on this process of *habit formation* shows that as a particular behavior in a particular behavior is repeatedly rewarded, the systems that control it shift from the dorsomedial to the ventral and dorsolateral aspects of the striatum (Figure 2; Yin, Mulcare, Kilario, Clouse, Holloway, Davis, et al., 2009). This shift is in part supported by the differential connectivity in these parts of the striatum, with the dorsomedial more strongly connected to the prefrontal and parietal cortices (involved in attention and working memory) and the other two parts of the striatum more strongly connected to the sensory and

motor cortices (Liljeholm & O’Doherty, 2012). That the process of routinizing behavior has a robust pathway embedded within some of the oldest structures in the brain speaks to the evolutionary importance of offloading effortful mental activities from the cortex as early and efficiently as possible. Thus, these regions are key for habit formation.

Is executive function a limited resource?

The answer to this question is both yes and no. Many readers will be familiar with the concept of ego depletion, or the idea that the “active self” that implements executive functions draws upon a finite resource that exhausts over time with repeated use, not unlike a fuel tank (Baumeister, Bratlavsky, Muraven, & Tice, 1998). Though there are literally hundreds of published studies showing the effect (Hagger, Wood, Stiff, & Chatzisarantis, 2010), it is likely that many of those studies are false positives or unreliable (Hagger, Chatzisarantis, Alberts, Anggono, Batailler, Birt, et al., 2016). A large, highly powered, preregistered study recently failed to replicate the ego depletion effect (Lurquin, Michaelson, Barker, Gustavson, von Bastian, Carruth, et al., 2016), and a meta-analysis uncovered evidence of publication bias in the ego depletion field such that studies finding the effect are much more likely to appear in print than those that do not (Carter & McCullough, 2014).

On a deeper level, there is strong counter-evidence to the basic ego depletion effect, for example that taking a short break, watching a fun film clip, or even smoking a cigarette can reverse the effect (see Inzlicht & Berkman, 2015 for a summary). Active-self processes such as executive function are unlikely to draw upon a limited physiological resource if simple psychological manipulations can replenish it. Even more suggestive, there is strong physiological evidence that the neuronal processes involved in executive function demand no more energy than simpler functions or even than the brain at rest (see Kurzban, 2010, for a review). There is simply no special physiological resource for executive function to deplete. The bottom line is that people get tired when they work hard – which is nothing new – but that, contrary to popular belief about ego depletion, that sense of fatigue is mostly psychological and can be short circuited by a short rest and a variety of positive experiences.

But what about the experience of depletion? Everyone has the intuition that some mental activities – certainly including executive function – feel hard and seem to drain our energy. The answer may be found by adjusting our understanding what exactly the limited resource is. The original formulation of ego depletion hypothesized a physiological resource, likely centered in the brain. That prediction is no longer tenable given the data. Newer models focus on the contributions of psychological and motivational factors to depletion instead beyond strictly physiological ones. For example, a shift in priorities from effortful, obligation-based, and prevention-focused “have-to” goals to enjoyable, desire-based, promotion-focused “want-to” goals could explain the decline in performance on tough cognitive tasks (Inzlicht, Schmeichel, & Macrae, 2014); perhaps the “resource” is prioritization. Another possibility is that depletion results from an interaction between psychological processes, such as perceptions of upcoming task demands and available resources, and physiological factors including the peripheral nervous system, hormones, and afferent inputs (Evans, Boggero, & Segerstrom, 2016).

A psychological model that fits particularly well with the characterization of executive function above focuses on its *opportunity cost* (Kurzban, Duckworth, Kable, & Myers, 2013). Because we can only focus our executive function capacity on one task at a time, then any time we engage in one executive function task we are likely forgoing others. The cost of what we're giving up is reflected in the sense of effort that comes along with executive function. The feeling of depletion, therefore, reflects the tipping point when the cost of putting off alternative tasks begins to outweigh the benefit of continuing on the current course of action (Berkman, Kahn, & Livingston, 2016).

The evidence at this point indicates that executive function is limited in terms of bandwidth – how much can be done or stored or attended to in a given moment – but not in terms of duration in the ego depletion sense. That limit stems directly from the properties of the executive function system: the facts that only a small amount of information can be consciously accessible and operated upon in a given moment (Unsworth, Fukuda, Awh, & Vogel, 2015), and that we actively track the processing costs of potential cognitive operations with respect to ongoing goals (Westbrook & Braver, 2015). For precisely this reason, executive function was likened by the mathematician and philosopher Alfred North Whitehead to cavalry in an army, “Operations of thought are like cavalry charges in a battle – they are strictly limited in number, they require fresh horses, and must only be made at decisive moments.” (pp. 61; Whitehead, 1911).

Can executive function be improved with practice?

There is naturally great interest in the question of whether executive function can be improved, expanded, or strengthened with practice given its bandwidth limitations. Study of this kind of “brain training” is an active research area and a controversial one. Some researchers make claims about the ability to improve executive function with training (Jaeggi, Buschkuhl, Jonides, & Shah, 2011), though these claims have been tempered by compelling counter-evidence (Redick, Shipstead, Harrison, Hicks, Fried, Hambrick, et al., 2013). A fair characterization of the research to date is that people can certainly improve on a given executive function *task* with practice, but there is no evidence that practice generalizes to other, even closely related tasks, and task-specific improvements are unlikely to endure over time (Berkman, 2016).

The core issue in executive function training is *transfer*, or whether the improvements on a training task generalize to other tasks. In some theories such as the Strength Model, on which the ego depletion hypothesis is based, executive function is a common resource that is shared across many discrete capacities (e.g., working memory and self-control), so expanding that common resource should improve a range of executive abilities (Muraven, 2010). However, counter-evidence to ego depletion specifically and the Strength Model generally have raised the question about whether a common underlying resource even exists (Inzlicht et al., 2014). A recent meta-analysis of studies attempting to train one form of executive function, self-control, revealed a negligible transfer effect (Inzlicht & Berkman, 2015). Additionally, at least two highly-powered studies have failed to find generalizable training effects on executive function despite showing practice effects on the training task (Miles, Sheeran, Baird, Macdonald, Webb, & Harris, in press; Redick et al., 2013).

What is happening? Neuroscientific investigations provide some clues. A series of training studies on inhibitory control, an executive function involving the prevention of ongoing or prepotent behavior, found that performance on an inhibitory control task improves with practice and does not transfer to other tasks. Interestingly, to the degree that performance on the training task improved, activity in the lateral prefrontal regions and dACC that is associated with successful inhibitory control shifted earlier in time, peaking in anticipation of the need for control (Beauchamp, Kahn, & Berkman, 2016; Berkman, Kahn, & Merchant, 2014). This effect can be characterized as a *reactive-to-proactive shift* in the neural activation involved in inhibitory control, and is akin to gently applying a car's brakes when a light turns yellow instead of slamming on the brakes only upon a red light.

The observed shift in brain activity from later to earlier in time fits well with the general characteristics of executive function described earlier. Inhibitory control feels hard and occupies attention, so it is beneficial to the individual to automate the operation when possible. With enough practice and exposure, the habit learning system discovers regularities in the environment that allow the need for inhibitory control to be anticipated using contextual cues. Just as the frequent association of a yellow light with a red light teaches experienced drivers to automatically move their foot to the brake when seeing a yellow, so too do participants in inhibitory control training studies learn the specific task cues that anticipate the need for control. This cue-learning effect in training occurs automatically (Lenartowicz, Verbruggen, Logan, & Poldrack, 2011), suggesting that performance improvements during inhibitory control training studies are a result of the transfer of at least some effortful behavior to the habit system. Habits increase efficiency during goal striving.

This habit learning process also explains the lack of transfer to new tasks. The advantages of executive function are mirrored in the limitations of the habit learning system. Specifically, while executive function evolved to deal with novel challenges, habit learning evolved for routine ones. Habits create efficiency by shrinking the range of responses in a situation down to one behavior. By function, they forestall new and creative behaviors in that situation. Habitual behaviors are triggered by specific contextual cues, which is why habits do not require vigilant and costly monitoring; that work is offloaded to more efficient stimulus-response mappings. The tradeoff is that habitual behaviors are necessarily tied to a particular context. If the cues that had been associated with a response change, then the habitual response will no longer emerge. For example, the ease of slowing on a yellow would be lost if the cue that preceded a red light suddenly became blue instead. In the case of executive function, training doesn't transfer to new contexts (or tasks) because the cues are different. The brain treats the tests of transfer as novel tasks, which is exactly what executive function evolved to deal with in the first place.

Lessons learned from neuroscience about “the way”

The neuroscience literature on executive function offers some practical if not entirely hopeful advice about the “way” of behavior change. The first lesson is that executive function feels hard for a reason. It is a serial process, so the sense of effort that accompanies executive function is a signal that working on a difficult task necessarily means losing out on other opportunities. In other words, effort reflects an opportunity cost. In this view, effort

also signals one's internal priorities; the more important the alternatives are, the harder a focal task will feel. The inverse is also true: a given task will feel relatively easy when it is more important to a person than the alternative choices. Consultants and coaches can work with clients to reflect on their priorities and make them explicit, which can explain why some goals feel harder than others.

The mental processes related to the “way” operate sequentially, not in parallel. Executive functions can only be performed one at a time, so the most important ones should come first even if executive processing will not exhaust over time with use. Based on the portrait of executive function drawn here, the factors that influence the capacity for executive function most directly are other concurrent cognitive operations and the relative importance of the task compared to other possibilities. Together, this suggests that it is optimal to carve out dedicated, distraction-free time to work on important novel tasks and challenges (Berkman & Rock, 2014). Our cognitive bandwidth is precious and operates most efficiently in (mental) solitude. Licensing clients to reserve work time specifically for new tasks can help.

Our executive function abilities evolved to help us deal with novel challenges. So, the precious resource of executive function should be brought to bear on any and all aspects of behavior change, such as goal setting, that benefit from openness to new ideas, broadened attention, and a wide survey of possibilities. In contrast, habit formation evolved to create efficiency by rigidly attaching one behavior to one cue. Habits can be formed to aid in other aspects of behavior change, such as goal striving, that benefit from a narrower focus and relatively consistent, fixed behaviors in a given situation.

Finally, there is not much evidence that executive function can be improved broadly by focused interventions (e.g., Lumosity; Redick et al., 2013; Shute, Ventura, & Ke, 2015), and some compelling counter-evidence. However, complex mental operations can become routinized by leveraging the habit learning system (Foerde, Knowlton, & Poldrack, 2006). Habit learning is facilitated when the new behavior is consistently preceded by specific cues and then rewarded. This procedure can be particularly useful for behavior change if the new behavior will occur repeatedly in similar contexts. Research is underway to test whether a highly variable set of cues used in training can broaden the range of contexts to which training effects generalize. Nonetheless, some executive functions such as working memory may simply be fixed capacities for neuroarchitectural reasons (Zhang & Luck, 2008). Rather than attempting to improve executive function generally, consultants and coaches should help their clients focus on improving specifically the skillsets relevant to the goal or new behavior. These will improve with practice and, with some proper motivation, become habitual in time.

The neuroscience of the “will”: Motivation, Reward, and Subjective Value

The question of what motivates behavior, in a general sense, runs at least back to the Greeks, with Plato's famous analogy of the charioteer and his horses, through William James and Abraham Maslow, and continues to this day. In contrast, the question of what motivates behavior *change* has received considerably less attention. Psychologists have developed taxonomies of different “stages of change” to capture individual variability in readiness to

engage in sustained behavior change (Transtheoretical Model; Prochaska, DiClemente, & Norcross, 1992), and of different types of behaviors within a person to capture relatively self-motivated, “intrinsic” versus more externally-motivated, “extrinsic” types of goals (Self-Determination Theory; Deci & Ryan, 2000). Much of this work is descriptive rather than prescriptive – it says what motivation is but does not indicate how to increase it. A person can be confidently described as in the precontemplation stage, but there is not much evidence-backed knowledge about moving him or her to the contemplation stage; likewise, some behaviors are clearly extrinsically motivated, though there is a lack of prescriptive advice about how one can transform them into intrinsically motivated ones.

As it did with studies on the “way,” neuroimaging research provides some clues about how to increase motivation to change a specific behavior. In this section, I review neuroscientific insights into the “way” of behavior change surrounding three questions that are relevant to consulting psychology. Which brain systems are involved in motivational processes? How do those systems interact with other networks in the brain? And what does neuroscience indicate about motivating behavior change?

How and where is motivation represented in the brain?

Motivation is conceptualized here as the strength of the desire to attain a particular outcome, irrespective of how pleasant or unpleasant the experience of actually attaining it is. This distinction between the motivational component of a reward – “wanting” – and the hedonic component of consuming it – “liking” – is maintained with remarkable evolutionary consistency in the brains of both humans and animals (Berridge & Robinson, 2003). I focus here on the “wanting” side because of its direct bearing on behavior and behavior change. Wanting a reward is closely tied with activity of mesolimbic dopaminergic neurons, particularly within the ventral striatum and ventromedial prefrontal cortex (Berridge, 2006; Figure 2), which is sometimes also called the orbitofrontal cortex (Wallis, 2007). Of course, there are many other regions and interactions involved in reward learning, but I focus on these because they are the best characterized in terms of human functional neuroanatomy to date.

The dopaminergic reward system has been conserved evolutionarily because it plays a critical role in the reinforcement learning cycle. When a particular behavior in a given context it is rewarded, that behavior and context are paired and tagged with reward value for later repetition (Rescorla & Wagner, 1972). Reinforcement learning is why behaviors that are rewarded are likely to be repeated in the future. (This is also why the dopamine system is implicated in addictive behavior.) The amount of cumulative, learned reward value of a behavior is its expected value, sometimes referred to as subjective value (Rangel & Hare, 2010). In short, subjective value represents the amount of reward that an actor expects to receive for a given action, largely based on past learning. This learning cycle is one of the key impediments to behavior change: old behavior has been rewarded and new behavior has not. A protein called brain-derived neurotrophic factor (BDNF) is important for maintaining new behaviors after engaging in them initially because of its critical role in memory consolidation (Bekinschtein et al., 2008). As described in the following sections, the key to

launching this reward learning and consolidation cycle is finding ways to increase the subjective value of new behavior.

A notable feature of activity in the ventromedial prefrontal cortex is that it represents the subjective values of diverse types of actions, presumably to facilitate “apples to oranges” decisions between qualitatively different behaviors (Levy & Glimcher, 2011). For example, activity in the ventromedial prefrontal cortex tracks the value of approach appetitive and avoiding aversive stimuli (Tom, Fox, Trepel, & Poldrack, 2007), and also the subjective value of a range of stimulus types, including food, money, gains for the self and others, charitable decisions, and emotional and utilitarian benefits of moral actions (Hare, Camerer, Knoepfle, O’Doherty, & Rangel, 2010; Hutcherson, Montaser-Kouhsari, Woodward, & Rangel, 2015; Lebreton, Jorge, Michel, Thirion, & Pessiglione, 2009; Zaki, Lopez, & Mitchell, 2014). These findings converge on the idea that the ventromedial prefrontal cortex plays a central role in tracking the subjective value of different kinds of actions during choice, which strongly implicates that region in motivational processing during behavior change.

How do motivation regions interact with other brain systems?

One way to approach the deeper issue of where motivation originates is to examine the connectivity of its neural systems. In the same way that it is adaptive to humans and informative to scientists that sensory and motor regions in the brain are adjacent and highly interconnected, the regions involved in motivation are themselves intertwined with several other brain networks. Those interrelations contain insights about how motivation operates and how it might be increased in the service of behavior change.

As Self-Determination Theory suggests, autonomously choosing to engage in a behavior (relative to being forced) increases performance on that behavior because autonomy is an intrinsic motive. At the neural level, autonomy also prevents a reduction in reward system activity in the face of negative feedback, particularly in the ventromedial prefrontal cortex (Murayama, Matsumoto, Izuma, Sugiura, Ryan, Deci, et al., 2013). Interestingly, the ventromedial prefrontal cortex has also been found to be active in studies of self-processing and particularly of *self-affirmation*, such as considering one’s core personal values (Cascio, O’Donnell, Tinney, Lieberman, Taylor, Strecher, et al., 2016). Brain activation related to self-affirmation during health messaging has even been shown to predict the eventual degree of health behavior change that would follow (Falk, O’Donnell, Cascio, Tinney, Kang, Lieberman, et al., 2015). Finally, a meta-analysis using the Neurosynth study database (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011) found that the ventromedial prefrontal cortex was one of the largest regions of overlap between 812 studies on identity (“self” and “self-referential” terms in the database) and 324 subjective value and reward (“value” term in the database). The meta-analysis contained several regions along the medial cortical wall including the ventromedial prefrontal cortex, the posterior cingulate cortex, and the mid-cingulate. The ventromedial prefrontal cortex was the single largest cluster to be consistently associated with both identity and value.

The overlap between intrinsic goals, core values, and subjective value has several implications for consulting psychology. First, identity (e.g., self-concept) and subjective

value are closely functionally connected to one another. This is not a surprise given the extensive evidence from social psychology and other fields that people have disproportionate positive regard for themselves (and behaviors related to the self) compared to others (Greenwald, 1980; Pelham & Swann, 1989). We want, and perhaps need, to see our selves as good (Rosenberg, 1979). Second, the value derived from identity and other self-related processes may have a special status compared to other sources of value (e.g., monetary) because of the high degree of overlap in the neural systems and conceptual representation of identity and value. It may even be that identity and value are inseparable, leading one researcher to hypothesize that the defining function of the self is to organize and prioritize the world by assigning it motivational significance (Northoff & Hayes, 2011). By this definition, the self-concept is exactly the set of places, things, and actions in the world that hold value.

It is important to note that the valuation process subserved by the vmPFC reflects not only positive value, but negative value as well. For example, just as social affiliation holds positive value, the threat of social rejection can be highly negative in value. The experience of social rejection invokes similar brain networks as physical pain (Lieberman & Eisenberger, 2015). Beyond its unpleasantness, this experience can enhance defensiveness and facilitate a stress response that detracts from other ongoing goals because it narrows attentional focus on the social threat (Muscatell et al., 2016).

The ventromedial prefrontal cortex and related dopaminergic motivational structures also interact with cognitive networks, including those related to executive function (Botvinick & Braver, 2015). The ventromedial prefrontal cortex appears to be a point of convergence where the motivational value of various options in a choice are integrated, notably including both effortful actions that require cognitive control and also easier, more hedonic ones (Bartra, McGuire, & Kable, 2013). For example, the dorsolateral prefrontal cortex is functionally connected with the ventromedial prefrontal cortex when higher-order goals such as health concerns or social factors are made salient (Hare et al., 2010; Hutcherson, Plassman, Gross, & Rangel, 2012). There is also evidence that the value of potential actions are reflected in the ventromedial prefrontal cortex before any specific action plans is selected (Wunderlich, Rangel, & O'Doherty, 2010), but that value signals provide input to downstream brain regions that are responsible for selecting and implementing behavior (Hare, Schultz, Camerer, O'Doherty, & Rangel, 2011). Taken together, then, the emergent view from the neuroscience literature is that the ventromedial prefrontal cortex receives a variety of value signals relevant to decisions about behavior, and its activation reflects a dynamic value integration process that subsequently biases behavior toward higher-valued actions. A promising route to increasing motivation, then, is identifying the value inputs to a new behavior (i.e., the reasons why the behavior is or is not valued) and learning ways to modulate them. I address this possibility in the next section.

How can motivation be increased?

The neurally-informed model described above suggests that motivation is guided by an integration of the value of features of the behavioral options. Behavior change can be accomplished by amplifying the value of the new (goal-related) behavior, reducing the value

of old (goal-counter or goal-unrelated) behaviors, or some combination of the two. A clear example of the effectiveness of the first approach is contingency management treatment for substance use disorders (Bigelow & Silverman, 1999), in which the value of drug abstinence is increased with monetary incentives. A meta-analysis found this approach to have an effect size $d = 0.42$ on treatment for alcohol, tobacco, and illicit drugs, which was larger than therapy ($d = 0.25$) and outpatient treatment ($d = 0.37$), and comparable to methadone treatment for opiate use (Prendergast, Podus, Finney, Greenwell, & Roll, 2006). Similarly, “precommitting” to buy more healthy foods at the risk of losing financial incentives is more effective than having the incentives alone (Schwartz, Mochon, Wyper, Maroba, Patel, & Ariely, 2014). Monetary incentives also increase persistence at exercise (Cabanac, 1986), endurance on a cold-pressor task (Baker & Kirsch, 1991), and performance on a difficult cognitive task (Boksem, Meijman, & Lorist, 2006). Simple monetary payments are an effective way to motivate behavior change.

“Money walks,” as the saying goes, but its scarcity makes it a less than ideal option for many goal pursuit contexts. Above, I noted the deep connections between identity and motivation. Other researchers have, too, and are now beginning to deploy identity interventions to increase motivation. For example, one study leveraged the fact that most people consider willpower to be a desirable trait (Magen & Gross, 2007). The participants in that study completed an executive function task twice, and in between were randomly assigned to reconstrue *the task itself* as a measure of their own willpower or not. Performance improved from the first to the second run only among participants whose perceptions of the task were changed from non-diagnostic to diagnostic of willpower. Similarly, noting that identity is somewhat susceptible to cognitive shifts such as framing, construal, or priming effects, other researchers used a simple “noun-verb” manipulation to increase motivation for behavior change, presumably through a subtle shift in the extent to which the new behavior is construed as identity-relevant. For example, phrasing questions about voting intentions in terms of identity (noun: “being a voter”) instead of an action (verb: “voting”) increased voting intentions and actual turnout in statewide elections (Bryan, Walton, Rogers, & Dweck, 2011). In another study, participants were less likely to cheat by claiming money they were not entitled to if that behavior was described as a (negative) identity (noun: “being a cheater”) instead of an action (verb: “cheating”); Bryan, Adams, & Monin, 2013). Each of these results is consistent with the idea that identity can influence motivation, presumably by highlighting the subjective value of desired (e.g., “voter”, “willpower”) or undesired (e.g., “cheater”) identity. This path is a promising future direction for motivation interventions because it is low-cost, modest in scope, and easily scalable to a broad range of populations and types of desired identities.

Finally, merely highlighting certain attributes of a behavior can alter the value placed on that behavior. After all, our attentional bandwidth is fairly narrow, so not all relevant properties will be equally salient at all times. For example, people’s motivation to act on a choice option increases as attention is allocated to it (Krajbich, Armel, & Rangel, 2010). In another study (Hare et al., 2011), participants were presented with health-versus-taste decisions with or without reminders about health. As expected, health reminders increased the likelihood of healthy choices. Tellingly, the healthiness rating of the foods (assessed earlier, and separate from the tastiness) was strongly correlated with activity in the ventromedial prefrontal cortex

at the moment of decision, which in turn predicted the food choice. In contrast, when unhealthy foods were selected, the earlier *tastiness* ratings were correlated with ventromedial prefrontal cortex activity during choice. The results of these studies are broadly consistent with psychological framing effects (e.g., gain vs. loss frame; Kahneman & Tversky, 1984), whereby altering the relative salience of the features of a decision can dramatically change it. Though they are most often applied to decision-making, the neuroscientific evidence presented here suggests that motivation may also be susceptible to framing effects.

In light of the present framework, I focused on ways to increase motivation that are grounded in valuation. But there are other ways to increase motivation from complementary lines of research that nonetheless may be connected to subjective value. For example, Higgins has argued that people experience “value from fit” when their regulatory style (promotion versus prevention focus) matches the particular means through which goals are pursued (Higgins, Idson, Freitas, Spiegel, & Molden, 2003). A similar “matching” effect on motivation has been observed with achievement motivation and performance goals: people high in achievement motivation experience greater intrinsic motivation when provided with performance (vs. mastery) goals, whereas people low in achievement motivation experience greater intrinsic motivation with mastery (vs. performance) goals (Elliot & Harackiewicz, 1994). A plausible cause of these kinds of “matching” effects, which can be tested in future research, is that there is subjective value in experiencing fit between one’s dispositional tendencies and the nature of the goal at hand.

Lessons learned from neuroscience about “the will”

Neuroscientific investigations of motivation have established the major brain systems for motivation and identified ways that those systems interact with other parts of the brain. This knowledge, in turn, contains clues about how motivation works and how to increase it on the psychological level. Two are particularly relevant to consulting psychology.

The first lesson surrounds the extent to which motivation is tied to the past. The neural mechanisms of reinforcement learning are some of the most basic and ancient parts of our brains. For good reason, we evolved to be highly sensitive to learn where we receive rewards and to work hard to recreate the situations that brought them about. Attempting to change behavior in a systematic way by engaging in new behaviors, which have never been reinforced, often means working against this powerful system. Thus, wise advice for clients that is grounded in the neuroscience of motivation and reinforcement learning is to start behavior change with modest goals and reward even the smallest steps toward them. New behaviors emerge slowly because they are usually working against the power of prior reinforcement. Consultants and coaches can help clients anticipate and understand the difficulty of behavior change by explaining the neuroscience of reinforcement learning. Being cognizant of the challenges of behavior change can prevent frustration on both sides.

The second lesson is to leverage the intrinsic connections between the motivation system and other parts of the brain, particularly self and identity. The elaborated web of memories, beliefs, values, objects, and relationships that comprise our sense of self is paralleled perhaps only by executive function in its distinctiveness to humans. And it may offer a pathway to behavior change and goal achievement that is just as potent. A behavior will hold

greater subjective value to the degree that it is related to one's core values and sense of self. Identity-linked goals are more likely to be successful than identity-irrelevant or identity-counter ones. Consultants and coaches can be particularly helpful to clients in this arena by helping them discover core aspects of their self-concepts and the ways those aspects are linked to the behavior change at hand. And remember that identity is not a fixed construct, but rather is susceptible to framing, reconstrual, and other kinds of subtle influences. To some extent, motivation can be gained by finding ways to think about goals that makes their connection to important parts of one's identity salient. Sometimes it is easier for other people to make these connections than for us because they have more distance from them (Berkman & Rock, 2014); coaches can be particularly helpful in this regard. Paying people works, too, but connecting goals to the self-concept in various ways may be a more sustainable and accessible approach to increasing motivation.

Conclusion

Pursing goals and changing behavior is hard. Neuroscience will never change that fact, but it can provide some brain-level explanations for the difficulty as well as some new insights about how to mitigate it. This article reviewed the neuroscientific literatures on the "way" of goal pursuit – the set of cognitive skills, capacities, and abilities collectively known as executive function – and the "will" – the motivational factors that propel behavior. Although parts of the "way" are limited by constraints that may be difficult to change, the "will" can be influenced by incentives both within the person and without. Though neuroscientific investigations into long-term behavior change are only just starting to emerge they have already begun to contribute to the body of practical scientific knowledge about goals. The science and practice of consulting psychology will benefit directly from this research in the coming years.

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References

- Alvarez JA, Emory E. Executive function and the frontal lobes: A meta-analytic review. *Neuropsychology Review*. 2006; 16(1):17–42. [PubMed: 16794878]
- Baker SL, Kirsch I. Cognitive mediators of pain perception and tolerance. *Journal of Personality and Social Psychology*. 1991; 61(3):504–510. [PubMed: 1941522]
- Banich MT. Executive function: The search for an integrated account. *Current Directions in Psychological Science*. 2009; 18(2):89–94.
- Bartra O, McGuire JT, Kable JW. The valuation system: A coordinate-based meta-analysis of BOLD fMRI experiments examining neural correlates of subjective value. *NeuroImage*. 2013; 76:412–427. [PubMed: 23507394]
- Baumeister RF, Bratslavsky E, Muraven M, Tice DM. Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*. 1998; 74(5):1252–1265. [PubMed: 9599441]
- Beauchamp KG, Kahn LE, Berkman ET. Does inhibitory control training transfer?: behavioral and neural effects on an untrained emotion regulation task. *Social Cognitive and Affective Neuroscience*. 2016; 11(9):1374–1382. [PubMed: 27217106]

- Bekinschtein P, Cammarota M, Katze C, Slipczuk L, Rossato JI, Goldin A, et al. BDNF is essential to promote persistence of long-term memory storage. *Proceedings of the National Academy of Sciences*. 2008; 105(7):2711–2716.
- Berkman, ET. Self-regulation training. In: Vohs, KD., Baumeister, RF., editors. *Handbook of Self-Regulation*. 3. New York: Guilford Press; 2016. p. 440-457.
- Berkman ET, Rock D. AIM: An integrative model of goal pursuit. *NeuroLeadership Journal*. 2014; 5:1–11.
- Berkman, ET., Kahn, LE., Livingston, JL. *Self-Regulation and Ego Control*. New York: Elsevier; 2016. Valuation as a mechanism of self-control and ego depletion; p. 255-279.
- Berkman ET, Kahn LE, Merchant JS. Training-induced changes in inhibitory control network activity. *The Journal of Neuroscience*. 2014; 34(1):149–157. [PubMed: 24381276]
- Berkman ET, Lieberman MD. Using neuroscience to broaden emotion regulation: Theoretical and methodological considerations. *Social and Personality Psychology Compass*. 2009; 3(4):475–493. [PubMed: 24052803]
- Berkman ET, Lieberman MD. Approaching the bad and avoiding the good: Lateral prefrontal cortical asymmetry distinguishes between action and valence. *Journal of Cognitive Neuroscience*. 2010; 22(9):1970–1979. [PubMed: 19642879]
- Berridge KC. The debate over dopamine's role in reward: The case for incentive salience. *Psychopharmacology*. 2006; 191(3):391–431. [PubMed: 17072591]
- Berridge KC, Robinson TE. Parsing reward. *Trends in Neurosciences*. 2003; 26(9):507–513. [PubMed: 12948663]
- Bigelow, GE., Silverman, K. Theoretical and empirical foundations of contingency management treatments for drug abuse. In: Higgins, ST., Silverman, K., editors. *Motivating Behavior Change Among Illicit-Drug Abusers: Research on Contingency Management Interventions*. Washington, DC: American Psychological Association; 1999. p. 15-31.
- Boksem MAS, Meijman TF, Lorist MM. Mental fatigue, motivation and action monitoring. *Biological Psychology*. 2006; 72(2):123–132. [PubMed: 16288951]
- Botvinick M, Braver T. Motivation and cognitive control: From behavior to neural mechanism. *Annual Review of Psychology*. 2015; 66(1):83–113.
- Bryan CJ, Adams GS, Monin B. When cheating would make you a cheater: Implicating the self prevents unethical behavior. *Journal of Experimental Psychology: General*. 2013; 142(4):1001–1005. [PubMed: 23127418]
- Bryan CJ, Walton GM, Rogers T, Dweck CS. Motivating voter turnout by invoking the self. *Proceedings of the National Academy of Sciences*. 2011; 108(31):12653–12656.
- Cabanac M. Money versus pain: Experimental study of a conflict in humans. *Journal of the Experimental Analysis of Behavior*. 1986; 46(1):37–44. [PubMed: 3746186]
- Carter EC, McCullough ME. Publication bias and the limited strength model of self-control: Has the evidence for ego depletion been overestimated? *Frontiers in Psychology*. 2014; 5(1):1–11. [PubMed: 24474945]
- Cascio CN, O'Donnell MB, Tinney FJ, Lieberman MD, Taylor SE, Strecher VJ, Falk EB. Self-affirmation activates brain systems associated with self-related processing and reward and is reinforced by future orientation. *Social Cognitive and Affective Neuroscience*. 2016; 11(4):621–629. [PubMed: 26541373]
- Deci EL, Ryan RM. The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*. 2000; 11(4):227–268.
- Elliot AJ, Harackiewicz JM. Goal setting, achievement orientation, and intrinsic motivation: A mediational analysis. *Journal of Personality and Social Psychology*. 1994; 66(5):968–980. [PubMed: 8014838]
- Evans DR, Boggero IA, Segerstrom SC. The nature of self-regulatory fatigue and “ego depletion”: Lessons from physical fatigue. *Personality and Social Psychology Review*. 2016; 20(4):291–310.
- Falk EB, O'Donnell MB, Cascio CN, Tinney F, Kang Y, Lieberman MD, et al. Self-affirmation alters the brain's response to health messages and subsequent behavior change. *Proceedings of the National Academy of Sciences*. 2015; 112(7):201500247–7.

- Foerde K, Knowlton BJ, Poldrack RA. Modulation of competing memory systems by distraction. *Proceedings of the National Academy of Sciences*. 2006; 103(31):11778–11783.
- Fox MD, Snyder AZ, Vincent JL, Corbetta M, Van Essen DC, Raichle ME. The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences*. 2005; 102(27):9673–9678.
- Greenwald AG. The totalitarian ego: Fabrication and revision of personal history. *American Psychologist*. 1980; 35(7):603–618.
- Greicius MD, Supekar K, Menon V, Dougherty RF. Resting-State Functional Connectivity Reflects Structural Connectivity in the Default Mode Network. *Cerebral Cortex*. 2008; 19(1):72–78. [PubMed: 18403396]
- Hagger MS, Chatzisarantis N. A multi-lab pre-registered replication of the ego-depletion effect. *Perspectives on Psychological Science*. 2016; 11(4):546–573. [PubMed: 27474142]
- Hagger MS, Wood C, Stiff C, Chatzisarantis NLD. Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin*. 2010; 136(4):495–525. [PubMed: 20565167]
- Hare TA, Camerer CF, Knoepfle DT, O’Doherty JP, Rangel A. Value computations in ventral medial prefrontal cortex during charitable decision making incorporate input from regions involved in social cognition. *The Journal of Neuroscience*. 2010; 30(2):583–590. [PubMed: 20071521]
- Hare TA, Schultz W, Camerer CF, O’Doherty JP, Rangel A. Transformation of stimulus value signals into motor commands during simple choice. *Proceedings of the National Academy of Sciences*. 2011; 108(44):18120–18125.
- Higgins ET, Chen Idson L, Freitas AL, Spiegel S, Molden DC. Transfer of value from fit. *Journal of Personality and Social Psychology*. 2003; 84(6):1140–1153. [PubMed: 12793581]
- Hutcherson CA, Montaser-Kouhsari L, Woodward J, Rangel A. Emotional and utilitarian appraisals of moral dilemmas are encoded in separate areas and integrated in ventromedial prefrontal cortex. *The Journal of Neuroscience*. 2015; 35(36):12593–12605. [PubMed: 26354924]
- Hutcherson CA, Plassmann H, Gross JJ, Rangel A. Cognitive regulation during decision making shifts behavioral control between ventromedial and dorsolateral prefrontal value systems. *The Journal of Neuroscience*. 2012; 32(39):13543–13554. [PubMed: 23015444]
- Inzlicht M, Berkman E. Six questions for the resource model of control (and some answers). *Social and Personality Psychology Compass*. 2015; 9(10):511–524. [PubMed: 28966660]
- Inzlicht M, Schmeichel BJ, Macrae CN. Why self-control seems (but may not be) limited. *Trends in Cognitive Sciences*. 2014; 18(3):127–133. [PubMed: 24439530]
- Jaeggi SM, Buschkuhl M, Jonides J, Shah P. Short- and long-term benefits of cognitive training. *Proceedings of the National Academy of Sciences*. 2011; 108(5):10081–10086.
- Kahneman D, Tversky A. Values, choices and frames. *American Psychologist*. 1984; 39(4):341–350.
- Kouneiher F, Charron S, Koechlin E. Motivation and cognitive control in the human prefrontal cortex. *Nature Neuroscience*. 2009
- Krajibich I, Armel C, Rangel A. Visual fixations and the computation and comparison of value in simple choice. *Nature Neuroscience*. 2010; 13(10):1292–1298. [PubMed: 20835253]
- Kruglanski AW, Shah JY, Fishbach A, Friedman R, Chun WY, Sleeth-Keppler D. A theory of goal systems. *Advances in Experimental Social Psychology*. 2002; 34(1):331–378.
- Kurzban R. Does the brain consume additional glucose during self-control tasks? *Evolutionary Psychology*. 2010; 8(2):244–259. [PubMed: 22947794]
- Kurzban R, Duckworth A, Kable JW, Myers J. An opportunity cost model of subjective effort and task performance. *The Behavioral and Brain Sciences*. 2013; 36(06):661–679. [PubMed: 24304775]
- Lebreton M, Jorge S, Michel V, Thirion B, Pessiglione M. An automatic valuation system in the human brain: Evidence from functional neuroimaging. *Neuron*. 2009; 64(3):431–439. [PubMed: 19914190]
- Lenartowicz A, Verbruggen F, Logan GD, Poldrack RA. Inhibition-related activation in the right inferior frontal gyrus in the absence of inhibitory cues. *Journal of Cognitive Neuroscience*. 2011; 23(11):3388–3399. [PubMed: 21452946]

- Levy DJ, Glimcher PW. Comparing apples and oranges: Using reward-specific and reward-general subjective value representation in the brain. *The Journal of Neuroscience*. 2011; 31(41):14693–14707. [PubMed: 21994386]
- Lieberman MD, Eisenberger NI. The dorsal anterior cingulate cortex is selective for pain: Results from large-scale reverse inference. *Proceedings of the National Academy of Sciences*. 2015; 112(49):15250–15255.
- Liljeholm M, O’Doherty JP. Contributions of the striatum to learning, motivation, and performance: an associative account. *Trends in Cognitive Sciences*. 2012; 16(9):467–475. [PubMed: 22890090]
- Lurquin JH, Michaelson LE, Barker JE, Gustavson DE, von Bastian CC, Carruth NP, Miyake A. No evidence of the ego-depletion effect across task characteristics and individual differences: A pre-registered study. *PLoS ONE*. 2016; 11(2):e0147770–20. [PubMed: 26863227]
- Magen E, Gross JJ. Harnessing the need for immediate gratification: Cognitive reconstrual modulates the reward value of temptations. *Emotion*. 2007; 7(2):415–428. [PubMed: 17516818]
- McClelland, DC. *Human Motivation*. Glenview, IL: Scott, Foresman and Company; 1985.
- Menon V, Uddin LQ. Saliency, switching, attention and control: a network model of insula function. *Brain Structure and Function*. 2010; 214(5–6):655–667. [PubMed: 20512370]
- Miles E, Sheeran P, Baird H, Macdonald I, Webb TL, Harris PR. Does self-control improve with practice? Evidence from a six-week training program. *Journal of Experimental Psychology: General*. :1–18. in press.
- Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*. 2001; 24:167–202.
- Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*. 2000; 41(1):49–100. [PubMed: 10945922]
- Muraven M. Building self-control strength: Practicing self-control leads to improved self-control performance. *Journal of Experimental Social Psychology*. 2010; 46(2):465–468. [PubMed: 20401323]
- Murayama K, Matsumoto M, Izuma K, Sugiura A, Ryan RM, Deci EL, Matsumoto K. How self-determined choice facilitates performance: A key role of the ventromedial prefrontal cortex. *Cerebral Cortex*. 2013; 25(5):1241–1251. [PubMed: 24297329]
- Muscattell KA, Dedovic K, Slavich GM, Jarcho MR, Breen EC, Bower JE, et al. Neural mechanisms linking social status and inflammatory responses to social stress. *Social Cognitive and Affective Neuroscience*. 2016; 11(6):915–922. [PubMed: 26979965]
- Nee DE, Brown JW, Askren MK, Berman MG, Demiralp E, Krawitz A, Jonides J. A meta-analysis of executive components of working memory. *Cerebral Cortex*. 2012
- Niendam TA, Laird AR, Ray KL, Dean YM, Glahn DC, Carter CS. Meta-analytic evidence for a superordinate cognitive control network subserving diverse executive functions. *Cognitive, Affective, and Behavioral Neuroscience*. 2012; 12(2):241–268.
- Northoff G, Hayes DJ. Is our self nothing but reward? *Biological Psychiatry*. 2011; 69(11):1019–1025. [PubMed: 21276963]
- Northoff G, Heinzl A, de Greck M, Bermpohl F, Dobrowolny H, Panksepp J. Self-referential processing in our brain—A meta-analysis of imaging studies on the self. *NeuroImage*. 2006; 31(1):440–457. [PubMed: 16466680]
- Pelham BW, Swann WB. From self-conceptions to self-worth: On the sources and structure of global self-esteem. *Journal of Personality and Social Psychology*. 1989; 57(4):672–680. [PubMed: 2795437]
- Prendergast M, Podus D, Finney J, Greenwell L, Roll J. Contingency management for treatment of substance use disorders: a meta-analysis. *Addiction*. 2006; 101(11):1546–1560. [PubMed: 17034434]
- Prochaska JO, DiClemente CC, Norcross JC. In search of how people change: Applications to addictive behaviors. *The American Psychologist*. 1992; 47(9):1102–1114. [PubMed: 1329589]
- Rangel A, Hare T. Neural computations associated with goal-directed choice. *Current Opinion in Neurobiology*. 2010; 20(2):262–270. [PubMed: 20338744]

- Redick TS, Shipstead Z, Harrison TL, Hicks KL, Fried DE, Hambrick DZ, et al. No evidence of intelligence improvement after working memory training: A randomized, placebo-controlled study. *Journal of Experimental Psychology: General*. 2013; 142(2):359–379. [PubMed: 22708717]
- Rescorla RA, Wagner AR. A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. *Classical Conditioning II Current Research and Theory*. 1972; 2:64–99.
- Roos LE, Knight EL, Beauchamp KG, Berkman ET, Faraday K, Hyslop K, Fisher PA. Acute stress impairs inhibitory control based on individual differences in parasympathetic nervous system activity. *Biological Psychology*. 2017; 125:58–63. [PubMed: 28268165]
- Rosenberg, M. *Conceiving the Self*. New York: Basic Books; 1979.
- Schwartz J, Mochon D, Wyper L, Maroba J, Patel D, Ariely D. Healthier by precommitment. *Psychological Science*. 2014; 25(2):538–546. [PubMed: 24390824]
- Shenhav A, Cohen JD, Botvinick MM. Dorsal anterior cingulate cortex and the value of control. *Nature Neuroscience*. 2016; 19(10):1286–1291. [PubMed: 27669989]
- Shipstead Z, Harrison TL, Engle RW. Working memory capacity and fluid intelligence: Maintenance and disengagement. *Perspectives on Psychological Science*. 2016; 11(6):771–799. [PubMed: 27899724]
- Shute VJ, Ventura M, Ke F. The power of play: The effects of Portal 2 and Lumosity on cognitive and noncognitive skills. *Computers & Education*. 2015; 80:58–67.
- Stuss DT. Functions of the frontal lobes: Relation to executive functions. *Journal of the International Neuropsychological Society*. 2011; 17(05):759–765. [PubMed: 21729406]
- Stuss, DT., Knight, RT. *Principles of Frontal Lobe Function*. 2. New York: Oxford University Press; 2012.
- Tom SM, Fox CR, Trepel C, Poldrack RA. The neural basis of loss aversion in decision-making under risk. *Science*. 2007; 315(5811):515–518. [PubMed: 17255512]
- Unsworth N, Fukuda K, Awh E, Vogel EK. Working memory delay activity predicts individual differences in cognitive abilities. *Journal of Cognitive Neuroscience*. 2015; 27(5):853–865. [PubMed: 25436671]
- Wallis JD. Orbitofrontal cortex and its contribution to decision-making. *Annual Review of Neuroscience*. 2007; 30(1):31–56.
- Westbrook A, Braver TS. Cognitive effort: A neuroeconomic approach. *Cognitive, Affective, and Behavioral Neuroscience*. 2015; 15(2):395–415.
- Whitehead, AN. *An Introduction to Mathematics*. New York: Holt; 1911.
- Wood W, Neal DT. A new look at habits and the habit-goal interface. *Psychological Review*. 2007; 114(4):843–863. [PubMed: 17907866]
- Wunderlich K, Rangel A, O'Doherty JP. Economic choices can be made using only stimulus values. *Proceedings of the National Academy of Sciences*. 2010; 107(34):15005–15010.
- Yarkoni T, Poldrack RA, Nichols TE, Van Essen DC, Wager TD. Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods*. 2011; 8(8):665–670. [PubMed: 21706013]
- Yin HH, Mulcare SP, Hilário MRF, Clouse E, Holloway T, Davis MI, et al. Dynamic reorganization of striatal circuits during the acquisition and consolidation of a skill. *Nature Neuroscience*. 2009; 12(3):333–341. [PubMed: 19198605]
- Zaki J, Lopez G, Mitchell JP. Activity in ventromedial prefrontal cortex covaries with revealed social preferences: Evidence for person-invariant value. *Social Cognitive and Affective Neuroscience*. 2014; 9(4):464–469. [PubMed: 23314009]
- Zhang W, Luck SJ. Discrete fixed-resolution representations in visual working memory. *Nature*. 2008; 453(7192):233–235. [PubMed: 18385672]

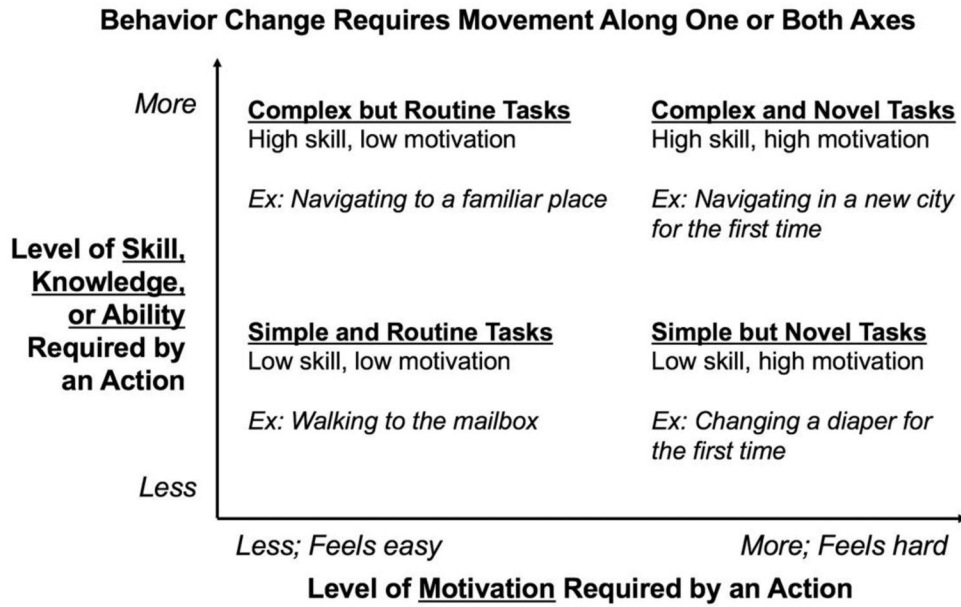


Figure 1.

Behavior can be divided into four broad categories defined by the level of motivation they demand (horizontal axis) and the level of skill or ability they require (vertical axis).

Behavior change typically involves moving from left-to-right, from bottom-to-top, or both. Moving from left-to-right increases the motivational demand (*why*) of an action, whereas moving from bottom-to-top increases the skill level (*how*). It is useful to identify the vector of change required during goal pursuit and to target motivational (horizontal) and cognitive (vertical) processes as necessary.

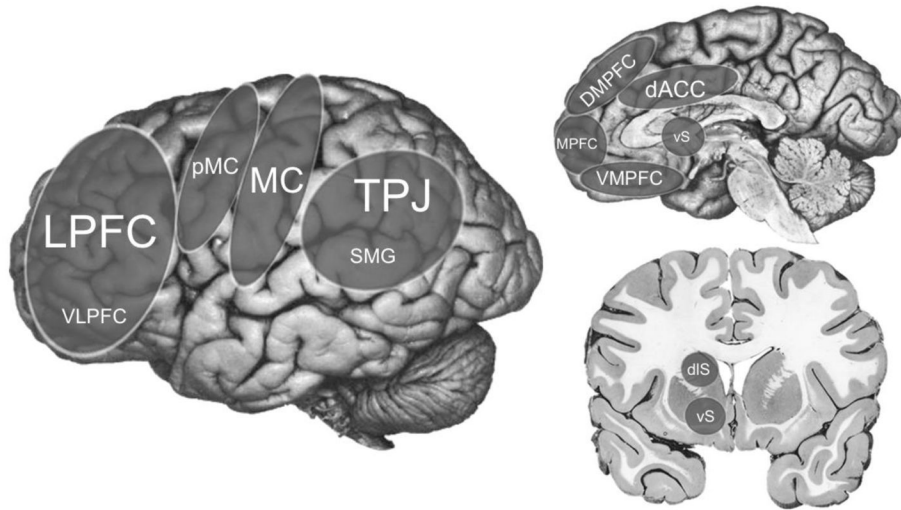


Figure 2.

Regions implicated in the will and the way. Left: Lateral view featuring the lateral prefrontal cortex (LPFC) and the ventrolateral prefrontal cortex (VLPFC), premotor cortex (pMC) and motor cortex (MC), and the temporalparietal junction (TPJ) and supramarginal gyrus (SMG). Top Right: Medial view featuring the dorsal anterior cingulate cortex (dACC) and ventral striatum (vS), and the dorsomedial (dmPFC), medial (mPFC) and ventromedial (vmPFC) aspects of the prefrontal cortex. Bottom Right: Coronal view featuring the ventral (vS) and dorsolateral (dlS) aspects of the striatum.

Table 1

Functional neuroanatomy of key networks

| Network | Primary regions | Major functions | Summary citation |
|---|---|--|---|
| Affective salience network | Dorsal anterior cingulate (dACC), anterior insula, subgenual ACC | Interoceptive awareness, emotional distress, pain | Menon & Uddin, 2010 |
| Cognitive control/Task-positive network | Lateral prefrontal cortex (IPFC), parietal cortex, dACC, temporalparietal junction (TPJ) | Attentional control, working memory, task switching | Niendam, Laird, Ray, Dean, Glahn, & Carter, 2012 |
| Default mode network | Medial prefrontal cortex (mPFC), medial temporal lobes, posterior cingulate cortex (PCC) | Task negative network, mind wandering, self-processing | Greicius, Supekar, Menon, & Dougherty, 2009 |
| Emotion regulation network | Ventrolateral prefrontal cortex (vlPFC), dorsolateral prefrontal cortex (dlPFC), IPFC | Cognitive reappraisal, self-distancing, emotional construal | Berkman & Lieberman, 2009 |
| Self-processing network | mPFC, PCC, TPJ, middle temporal lobe | Self-related cognition, introspection, self-consciousness, self-affirmation | Northoff, Heinzel, de Greck, Bermpohl, Dobrowolny, & Panksepp, 2006 |
| Valuation and reward network | Ventromedial prefrontal cortex (vmPFC), orbitofrontal cortex (OFC), ventral striatum (vS) | Valuation/evaluation, reward anticipation, reward learning, affective significance | Bartra, McGuire, & Kable, 2013 |