

ESCALADE

RECOVERY FOUNDATION

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The brain is a terrible master but a wonderful servant

The experience of addiction is that of the co-opting of the brain such that the organizing principle of one's life becomes feeding the addiction. This manifests as powerlessness. We find ourselves conducting our lives in contradiction to our principles, morals and deepest desires. It is said, *the alcoholic/addict will trade what he really wants for what he wants right now*. In the group of high achieving alcoholic/addicts we can invoke the definition of *a bottom* as:

being unable to lower our standards fast enough to keep up with our behavior

Regaining control of our lives requires regaining control of our brains. Making the brain our servant. It is an ongoing process. Our culture is designed to direct our brain to purchase, consume and act upon outside influences that may be subtle and not really serving the greater good. In active addiction we are also compelled to act upon internally generated impulses, from our primitive brain and limbic system areas, whose overwhelming drive is to feed the addiction.

The ability to focus our brain, in order to carry out the task at hand, and to maintain that focus through completion of the task is called **executive function**. It is not innate, although the potential to develop it is. Early life experiences, trauma and chemicals we imbibe during critical stages of our development impact its development. We will talk about this at length. The following pages include comprehensive treatments of executive function and our fear response.

Executive function and optimal brain efficiency require the establishment and development of healthy neural circuits, adequate neurotransmitters, functioning manufacture and reuptake of neurotransmitters. Our pleasure and passions are expressed through the manipulation of dopamine and other neurotransmitters. Substances of addiction, and processes of addiction cause a marked dopamine release, a profound reinforcing reward and a drive to continue receiving this reward. It is helpful to remember that all foods taste good to someone, while may repulse others. Similarly, all recreational activities are pleasurable to some but don't stimulate everyone. Finding those activities, hobbies habits and behaviors that elicit a dopamine response in the individual and pursuing them make for a happy life. On a cellular level, the pursuit of happiness is

merely the pursuit of dopamine flooding the appropriate circuits. Finding healthy and non-addictive ways to do this is the key to a happy sober life.

There is, however, more to optimal brain function than optimizing neural circuitry. We must have emotional balance for optimal functioning. I am referring to the neuroendocrine milieu which we generate, and in which the brain functions. This is a dynamic state and can be attributed to levels of adrenaline and cortisol predominantly. These hormonal responses, generated by the adrenal gland are related to our fear responses, state of health, level of anxiety and general sense of well being or lack thereof.

This is what explains test anxiety, performance anxiety “clutch” athletic performance and stage fright, for example. These responses are impacted by previous trauma, and early childhood development. Managing our adrenaline I refer to as managing our emotional state. This not only impacts performance but also is a large determinant of health and longevity. Brain mastery, and particularly 11th step work help us learn and practice managing our neuroendocrine milieu. We will talk about this in depth, also.

The level of adrenaline, whether generated by pleasurable circumstances, like sexual arousal, or frightening circumstances, impacts our judgment and ability to exercise optimal executive function. We are more impulsive, less contemplative and much more likely to relapse under the influence of an enhanced adrenaline response.

Executive functions

Executive functions (collectively referred to as **executive function** and **cognitive control**) are a set of [cognitive processes](#) that are necessary for the cognitive control of [behavior](#): selecting and successfully monitoring behaviors that facilitate the attainment of chosen goals. Executive functions include basic cognitive processes such as [attentional control](#), [cognitive inhibition](#), [inhibitory control](#), [working memory](#), and [cognitive flexibility](#). Higher order executive functions require the simultaneous use of multiple basic executive functions and include [planning](#) and [fluid intelligence](#) (e.g., [reasoning](#) and [problem solving](#)).^{[1][2][3]}

Executive functions gradually develop and change across the lifespan of an individual and can be improved at any time over the course of a person's life.^[2] Similarly, these cognitive processes can be adversely affected by a variety of events which affect an individual.^[2] Both [neuropsychological tests](#) (e.g., the [Stroop test](#)) and rating scales (e.g., the [Behavior Rating Inventory of Executive Function](#)) are used to measure executive functions. They are usually performed as part of a [more comprehensive assessment](#) to diagnose neurological and psychiatric disorders.

Cognitive control and [stimulus control](#), which is associated with [operant](#) and [classical conditioning](#), represent opposite processes (internal vs external or environmental, respectively) that compete over the control of an individual's elicited behaviors;^[4] in particular, inhibitory control is necessary for overriding stimulus-driven behavioral responses (stimulus control of behavior).^[2] The [prefrontal cortex](#) is necessary but not solely sufficient for executive functions;^{[2][5][6]} for example, the [caudate nucleus](#) and [subthalamic nucleus](#) also have a role in mediating inhibitory control.^{[2][7]}

Cognitive control is impaired in [addiction](#),^[7] [attention deficit hyperactivity disorder](#),^{[2][7]} [autism](#),^[8] and a number of other [central nervous system disorders](#). Stimulus-driven behavioral responses that are associated with a particular [rewarding stimulus](#) tend to dominate one's behavior in an addiction.^[7]

Contents

Neuroanatomy

Historically, the executive functions have been seen as regulated by the prefrontal regions of the frontal lobes, but it is still a matter of ongoing debate if that really is the case.^[5] Even though articles on prefrontal lobe lesions commonly refer to disturbances of executive functions and vice versa, a review found indications for the [sensitivity](#) but not for the [specificity](#) of executive function measures to frontal lobe functioning. This means that both frontal and non-frontal brain regions are necessary for intact executive functions. Probably the frontal lobes need to participate in basically all of the executive functions, but it is not the only brain structure involved.^[5]

[Neuroimaging](#) and [lesion](#) studies have identified the functions which are most often associated with the particular regions of the prefrontal cortex and associated areas.^[5]

- The [dorsolateral prefrontal cortex](#) (DLPFC) is involved with "on-line" processing of information such as integrating different dimensions of cognition and behavior.^[9] As such, this area has been found to be associated with verbal and design fluency, ability to maintain and [shift set](#), planning, response inhibition, working memory, organisational skills, reasoning, problem solving and abstract thinking.^{[5][10]}

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Side view of the brain, illustrating dorsolateral prefrontal and orbitofrontal cortex

- The [anterior cingulate cortex](#) (ACC) is involved in emotional drives, experience and integration.^[9] Associated cognitive functions include inhibition of inappropriate responses, decision making and motivated behaviors. Lesions in this area can lead to low drive states such as [apathy](#), [abulia](#) or [akinetic mutism](#) and may also result in low drive states for such basic needs as food or drink and possibly decreased interest in social or vocational activities and sex.^{[9][11]}
- The [orbitofrontal cortex](#) (OFC) plays a key role in impulse control, maintenance of set, monitoring ongoing behavior and socially appropriate behaviors.^[9] The orbitofrontal cortex also has roles in representing the value of rewards based on sensory stimuli and evaluating subjective emotional experiences.^[12] Lesions can cause

disinhibition, impulsivity, aggressive outbursts, sexual promiscuity and antisocial behavior.^[5]

Furthermore, in their review, Alvarez and Emory state that: "The frontal lobes have multiple connections to cortical, subcortical and brain stem sites. The basis of 'higher-level' cognitive functions such as inhibition, flexibility of thinking, problem solving, planning, impulse control, concept formation, abstract thinking, and creativity often arise from much simpler, 'lower-level' forms of cognition and behavior. Thus, the concept of executive function must be broad enough to include anatomical structures that represent a diverse and diffuse portion of the central nervous system."^[5]

The [cerebellum](#) also appears to be involved in mediating certain executive functions.^{[13][14]}

Hypothesized role

The executive system is thought to be heavily involved in handling novel situations outside the domain of some of our 'automatic' psychological processes that could be explained by the reproduction of learned [schemas](#) or set behaviors. Psychologists [Don Norman](#) and [Tim Shallice](#) have outlined five types of situations in which routine activation of behavior would not be sufficient for optimal performance:^{[15][page needed]}

1. Those that involve planning or decision making
2. Those that involve error correction or troubleshooting
3. Situations where responses are not well-rehearsed or contain novel sequences of actions
4. Dangerous or technically difficult situations
5. Situations that require the overcoming of a strong habitual response or resisting temptation.

A *prepotent response* is a response for which immediate [reinforcement](#) (positive or negative) is available or has been previously associated with that response.^{[16][page needed]}

Executive functions are often invoked when it is necessary to override prepotent responses that might otherwise be automatically elicited by stimuli in the external environment. For example, on being presented with a

potentially rewarding stimulus, such as a tasty piece of [chocolate cake](#), a person might have the automatic response to take a bite. However, where such behavior conflicts with internal plans (such as having decided not to eat chocolate cake while on a diet), the executive functions might be engaged to inhibit that response.

Although suppression of these prepotent responses is ordinarily considered adaptive, problems for the development of the individual and the culture arise when feelings of right and wrong are overridden by cultural expectations or when creative impulses are overridden by executive inhibitions. ^[17][\[page needed\]](#)

Historical perspective

Although research into the executive functions and their neural basis has increased markedly over recent years, the theoretical framework in which it is situated is not new. In the 1940s, the British psychologist [Donald Broadbent](#) drew a distinction between "automatic" and "controlled" processes (a distinction characterized more fully by [Shiffrin](#) and Schneider in 1977), ^[18] and introduced the notion of [selective attention](#), to which executive functions are closely allied. In 1975, the US psychologist [Michael Posner](#) used the term "cognitive control" in his book chapter entitled "Attention and cognitive control". ^[19]

The work of influential researchers such as Michael Posner, [Joaquin Fuster](#), [Tim Shallice](#), and their colleagues in the 1980s (and later [Trevor Robbins](#), Bob Knight, Don Stuss, and others) laid much of the groundwork for recent research into executive functions. For example, Posner proposed that there is a separate "executive" branch of the attentional system, which is responsible for focusing [attention](#) on selected aspects of the environment. ^[20] The British [neuropsychologist](#) Tim Shallice similarly suggested that attention is regulated by a "supervisory system", which can override automatic responses in favour of scheduling behaviour on the basis of plans or intentions. ^[21] Throughout this period, a consensus emerged that this control system is housed in the most anterior portion of the brain, the [prefrontal cortex](#) (PFC).

Psychologist [Alan Baddeley](#) had proposed a similar system as part of his model of [working memory](#) ^[22] and argued that there must be a component (which he named the "central executive") that allows information to be

manipulated in [short-term memory](#) (for example, when doing [mental arithmetic](#)).

Development

Further information: [Neurobiological effects of physical exercise § Cognitive control and memory](#)

The executive functions are among the last mental functions to reach maturity. This is due to the delayed maturation of the [prefrontal cortex](#), which is not completely [myelinated](#) until well into a person's third decade of life. Development of executive functions tends to occur in spurts, when new skills, strategies, and forms of awareness emerge. These spurts are thought to reflect maturational events in the frontal areas of the brain.^[23] Attentional control appears to emerge in infancy and develop rapidly in early childhood. Cognitive flexibility, goal setting, and information processing usually develop rapidly during ages 7–9 and mature by age 12. Executive control typically emerges shortly after a transition period at the beginning of adolescence.^[24] It is not yet clear whether there is a single sequence of stages in which executive functions appear, or whether different environments and early life experiences can lead people to develop them in different sequences.^[23]

Early childhood

[Inhibitory control](#) and [working memory](#) act as basic executive functions that makes it possible for more complex executive functions like problem-solving to develop.^[25] Inhibitory control and working memory are among the earliest executive functions to appear, with initial signs observed in infants, 7 to 12-months old.^{[23][24]} Then in the preschool years, children display a spurt in performance on tasks of inhibition and working memory, usually between the ages of 3 to 5 years.^{[23][26]} Also during this time, cognitive flexibility, goal-directed behavior, and planning begin to develop.^[23] Nevertheless, preschool children do not have fully mature executive functions and continue to make errors related to these emerging abilities – often not due to the absence of the abilities, but rather because they lack the awareness to know when and how to use particular strategies in particular contexts.^[27]

Preadolescence

Preadolescent children continue to exhibit certain growth spurts in executive functions, suggesting that this development does not necessarily occur in a linear manner, along with the preliminary maturing of particular functions as well. [23][24] During preadolescence, children display major increases in verbal working memory; [28] goal-directed behavior (with a potential spurt around 12 years of age); [29] response inhibition and selective attention; [30] and strategic planning and organizational skills. [24][31][32] Additionally, between the ages of 8 to 10, cognitive flexibility in particular begins to match adult levels. [31][32] However, similar to patterns in childhood development, executive functioning in preadolescents is limited because they do not reliably apply these executive functions across multiple contexts as a result of ongoing development of inhibitory control. [23]

Adolescence

Many executive functions may begin in childhood and preadolescence, such as inhibitory control. Yet, it is during adolescence when the different brain systems become better integrated. At this time, youth implement executive functions, such as inhibitory control, more efficiently and effectively and improve throughout this time period. [33][34] Just as inhibitory control emerges in childhood and improves over time, planning and goal-directed behavior also demonstrate an extended time course with ongoing growth over adolescence. [26][29] Likewise, functions such as attentional control, with a potential spurt at age 15, [29] along with working memory, [33] continue developing at this stage.

Adulthood

The major change that occurs in the brain in adulthood is the constant myelination of neurons in the prefrontal cortex. [23] At age 20–29, executive functioning skills are at their peak, which allows people of this age to participate in some of the most challenging mental tasks. These skills begin to decline in later adulthood. Working memory and spatial span are areas where decline is most readily noted. Cognitive flexibility, however, has a late onset of impairment and does not usually start declining until around age 70 in normally functioning adults. [23] Impaired executive functioning has been found to be the best predictor of functional decline in the elderly.

Models

Top-down inhibitory control

Aside from facilitatory or amplificatory mechanisms of control, many authors have argued for [inhibitory mechanisms](#) in the domain of response control,^[35] memory,^[36] selective attention,^[37] [theory of mind](#),^{[38][39]} emotion regulation,^[40] as well as social emotions such as empathy.^[41] A recent review on this topic argues that active inhibition is a valid concept in some domains of psychology/cognitive control.^[42]

Working memory model

One influential model is Baddeley's multicomponent model of working memory, which is composed of a central executive system that regulates three other subsystems: the phonological loop, which maintains verbal information; the visuospatial sketchpad, which maintains visual and spatial information; and the more recently developed episodic buffer that integrates short-term and long-term memory, holding and manipulating a limited amount of information from multiple domains in temporal and spatially sequenced episodes.^{[22][43]}

Supervisory attentional system (SAS)

Another conceptual model is the [supervisory attentional system](#) (SAS).^{[44][45]} In this model, contention scheduling is the process where an individual's well-established schemas automatically respond to routine situations while executive functions are used when faced with novel situations. In these new situations, attentional control will be a crucial element to help generate new schema, implement these schema, and then assess their accuracy.

Self-regulatory model

[Russell Barkley](#) proposed a widely known model of executive functioning that is based on [self-regulation](#). Primarily derived from work examining behavioral inhibition, it views executive functions as composed of four main abilities.^[46] One element is working memory that allows individuals to resist interfering information. A second component is the management of emotional responses in order to achieve goal-directed behaviors. Thirdly,

internalization of self-directed speech is used to control and sustain rule-governed behavior and to generate plans for problem-solving. Lastly, information is analyzed and synthesized into new behavioral responses to meet one's goals. Changing one's behavioral response to meet a new goal or modify an objective is a higher level skill that requires a fusion of executive functions including self-regulation, and accessing prior knowledge and experiences.

According to this model, the executive system of the human brain provides for the cross-temporal organization of behavior towards goals and the future and coordinates actions and strategies for everyday goal-directed tasks. Essentially, this system permits humans to self-regulate their behavior so as to sustain action and problem solving toward goals specifically and the future more generally. Thus, executive function deficits pose serious problems for a person's ability to engage in self-regulation over time to attain their goals and anticipate and prepare for the future.^[47]

Problem-solving model

Yet another model of executive functions is a problem-solving framework where executive functions is considered a macroconstruct composed of subfunctions working in different phases to (a) represent a problem, (b) plan for a solution by selecting and ordering strategies, (c) maintain the strategies in short-term memory in order to perform them by certain rules, and then (d) evaluate the results with error detection and error correction.^[48]

Lezak's conceptual model

One of the most widespread conceptual models on executive functions is Lezak's model.^[49] This framework proposes four broad domains of volition, planning, purposive action, and effective performance as working together to accomplish global executive functioning needs. While this model may broadly appeal to clinicians and researchers to help identify and assess certain executive functioning components, it lacks a distinct theoretical basis and relatively few attempts at validation.^[50]

Miller and Cohen's model

In 2001, Earl Miller and Jonathan Cohen published their article "An integrative theory of prefrontal cortex function", in which they argue that cognitive control is the primary function of the prefrontal cortex (PFC), and

that control is implemented by increasing the [gain](#) of sensory or motor [neurons](#) that are engaged by task- or goal-relevant elements of the external environment.^[51] In a key paragraph, they argue:

We assume that the PFC serves a specific function in cognitive control: the active maintenance of patterns of activity that represent goals and the means to achieve them. They provide bias signals throughout much of the rest of the brain, affecting not only visual processes but also other sensory modalities, as well as systems responsible for response execution, memory retrieval, emotional evaluation, etc. The aggregate effect of these bias signals is to guide the flow of neural activity along pathways that establish the proper mappings between inputs, internal states, and outputs needed to perform a given task.

Miller and Cohen draw explicitly upon an earlier theory of visual attention that conceptualises perception of visual scenes in terms of competition among multiple representations – such as colors, individuals, or objects.^[52] [Selective visual attention](#) acts to 'bias' this competition in favour of certain selected features or representations. For example, imagine that you are waiting at a busy train station for a friend who is wearing a red coat. You are able to selectively narrow the focus of your attention to search for red objects, in the hope of identifying your friend. Desimone and Duncan argue that the brain achieves this by selectively increasing the gain of neurons responsive to the color red, such that output from these neurons is more likely to reach a downstream [processing stage](#), and, as a consequence, to guide [behaviour](#). According to Miller and Cohen, this [selective attention](#) mechanism is in fact just a special case of cognitive control – one in which the biasing occurs in the sensory domain. According to Miller and Cohen's model, the PFC can exert control over input (sensory) or output (response) [neurons](#), as well as over assemblies involved in [memory](#), or [emotion](#). Cognitive control is mediated by reciprocal PFC [connectivity](#) with the [sensory](#) and [motor cortices](#), and with the [limbic system](#). Within their approach, thus, the term "cognitive control" is applied to any situation where a biasing signal is used to promote task-appropriate responding, and control thus becomes a crucial component of a wide range of psychological constructs such as [selective attention](#), error monitoring, [decision-making](#), [memory inhibition](#), and response inhibition.

Miyake and Friedman's model

Miyake and Friedman's theory of executive functions proposes that there are three aspects of executive functions: updating, inhibition, and shifting.^[53] A cornerstone of this theoretical framework is the understanding that individual differences in executive functions reflect both unity (i.e., common EF skills) and diversity of each component (e.g., shifting-specific). In other words, aspects of updating, inhibition, and shifting are related, yet each remains a distinct entity. First, updating is defined as the continuous monitoring and quick addition or deletion of contents within one's working memory. Second, inhibition is one's capacity to supersede responses that are prepotent in a given situation. Third, shifting is one's cognitive flexibility to switch between different tasks or mental states.

Miyake and Friedman also suggest that the current body of research in executive functions suggest four general conclusions about these skills. The first conclusion is the unity and diversity aspects of executive functions.^{[54][55]} Second, recent studies suggest that much of one's EF skills are inherited genetically, as demonstrated in twin studies.^[56] Third, clean measures of executive functions can differentiate between normal and clinical or regulatory behaviors, such as ADHD.^{[57][58][59]} Last, longitudinal studies demonstrate that EF skills are relatively stable throughout development.^{[60][61]}

Banich's "cascade of control" model

This model from 2009 integrates theories from other models, and involves a sequential cascade of brain regions involved in maintaining attentional sets in order to arrive at a goal. In sequence, the model assumes the involvement of the posterior [dorsolateral prefrontal cortex](#) (DLPFC), the mid-DLPFC, and the posterior and anterior dorsal [anterior cingulate cortex](#) (ACC).^[62]

The cognitive task used in the article is selecting a response in the [Stroop task](#), among conflicting color and word responses, specifically a stimulus where the word "green" is printed in red ink. The posterior DLPFC creates an appropriate attentional set, or rules for the brain to accomplish the current goal. For the Stroop task, this involves activating the areas of the brain involved in color perception, and not those involved in word comprehension. It counteracts biases and irrelevant information, like the fact that the

semantic perception of the word is more salient to most people than the color in which it is printed.

Next, the mid-DLPFC selects the representation that will fulfill the goal. The task-relevant information must be separated from other sources of information in the task. In the example, this means focusing on the ink color and not the word.

The posterior dorsal [anterior cingulate cortex](#) (ACC) is next in the cascade, and it is responsible for response selection. This is where the decision is made whether the Stroop task participant will say "green" (the written word and the incorrect answer) or "red" (the font color and correct answer).

Following the response, the anterior dorsal ACC is involved in response evaluation, deciding whether one's response were correct or incorrect. Activity in this region increases when the probability of an error is higher.

The activity of any of the areas involved in this model depends on the efficiency of the areas that came before it. If the DLPFC imposes a lot of control on the response, the ACC will require less activity.^[62]

Recent work using individual differences in cognitive style has shown exciting support for this model. Researchers had participants complete an auditory version of the Stroop task, in which either the location or semantic meaning of a directional word had to be attended to. Participants that either had a strong bias toward spatial or semantic information (different cognitive styles) were then recruited to participate in the task. As predicted, participants that had a strong bias toward spatial information had more difficulty paying attention to the semantic information and elicited increased electrophysiological activity from the ACC. A similar activity pattern was also found for participants that had a strong bias toward verbal information when they tried to attend to spatial information.^[63]

Assessment

Assessment of executive functions involves gathering data from several sources and synthesizing the information to look for trends and patterns across time and settings. Apart from standardized [neuropsychological tests](#), other measures can and should be used, such as [behaviour checklists](#), [observations](#), [interviews](#), and [work samples](#). From these, conclusions may be drawn on the use of executive functions.^[64]

There are several different kinds of instruments (e.g., performance based, self-report) that measure executive functions across development. These assessments can serve a diagnostic purpose for a number of clinical populations.

- Behavioural Assessment of Dysexecutive Syndrome (BADS)
- [Behavior Rating Inventory of Executive Function](#) (BRIEF). Ages 2-90 covered by different versions of the scale.^[65]^[unreliable medical source?]
- [Barkley Deficits in Executive Functioning Scales](#) (BDEFS)^[66]
- Behavioral Dyscontrol Scale (BDS)^[67]
- Comprehensive Executive Function Inventory (CEFI)
- CogScreen^[68]^[unreliable medical source?]
- [Continuous Performance Task](#) (CPT)
- Controlled Oral Word Association Test (COWAT)
- d2 Test of Attention
- [Delis-Kaplan Executive Function System](#) (D-KEFS)
- Digit Vigilance Test
- Figural Fluency Test
- Halstead Category Test
- [Hayling and Brixton tests](#)^[69]^[70]
- [Iowa gambling task](#)
- Kaplan Baycrest Neurocognitive Assessment (KBNA)
- Kaufman Short Neuropsychological Assessment
- [Paced Auditory Serial Addition Test](#) (PASAT)
- [Pediatric Attention Disorders Diagnostic Screener](#) (PADDS)
- [Rey-Osterrieth Complex Figure](#)
- Ruff Figural Fluency Test
- [Stroop task](#)
- [Tasks of Executive Control](#)
- [Test of Variables of Attention](#) (T.O.V.A.)
- [Tower of London Test](#)
- [Trail-Making Test](#) (TMT) or Trails A & B
- [Wisconsin Card Sorting Test](#) (WCST)
- Symbol Digit Modalities Test

Experimental evidence

The executive system has been traditionally quite hard to define, mainly due to what psychologist [Paul W. Burgess](#) calls a lack of "process-behaviour correspondence".^[71] That is, there is no single behavior that can in itself be

tied to executive function, or indeed [executive dysfunction](#). For example, it is quite obvious what reading-impaired patients cannot do, but it is not so obvious what exactly executive-impaired patients might be incapable of.

This is largely due to the nature of the executive system itself. It is mainly concerned with the dynamic, "online" co-ordination of cognitive resources, and, hence, its effect can be observed only by measuring other cognitive processes. In similar manner, it does not always fully engage outside of real-world situations. As [neurologist Antonio Damasio](#) has reported, a patient with severe day-to-day executive problems may still pass paper-and-pencil or lab-based tests of executive function.^[72]

Theories of the executive system were largely driven by observations of patients having suffered [frontal lobe](#) damage. They exhibited disorganized actions and strategies for everyday tasks (a group of behaviors now known as [dysexecutive syndrome](#)) although they seemed to perform normally when clinical or lab-based tests were used to assess more fundamental cognitive functions such as [memory](#), [learning](#), [language](#), and [reasoning](#). It was hypothesized that, to explain this unusual behaviour, there must be an overarching system that co-ordinates other cognitive resources.^[73]

Much of the experimental evidence for the neural structures involved in executive functions comes from laboratory tasks such as the [Stroop task](#) or the [Wisconsin Card Sorting Task](#) (WCST). In the Stroop task, for example, human subjects are asked to name the color that color words are printed in when the ink color and word meaning often conflict (for example, the word "RED" in green ink). Executive functions are needed to perform this task, as the relatively overlearned and automatic behaviour (word reading) has to be inhibited in favour of a less practiced task – naming the ink color. Recent [functional neuroimaging](#) studies have shown that two parts of the PFC, the [anterior cingulate cortex](#) (ACC) and the [dorsolateral prefrontal cortex](#) (DLPFC), are thought to be particularly important for performing this task.

Context-sensitivity of PFC neurons

Other evidence for the involvement of the PFC in executive functions comes from single-cell [electrophysiology](#) studies in non-human [primates](#), such as the [macaque](#) monkey, which have shown that (in contrast to cells in the posterior brain) many PFC neurons are sensitive to a conjunction of a stimulus and a context. For example, PFC cells might respond to a green cue

in a condition where that cue signals that a leftwards fast movement of the eyes and the head should be made, but not to a green cue in another experimental context. This is important, because the optimal deployment of executive functions is invariably context-dependent.

One example from Miller & Cohen involves a pedestrian crossing the street. In the United States, where cars drive on the [right side of the road](#), an American learns to look **left** when crossing the street. However, if that American visits a country where cars drive on the left, such as the United Kingdom, then the *opposite* behavior would be required (looking to the **right**). In this case, the automatic response needs to be suppressed (or augmented) and executive functions must make the American look to the right while in the UK.

Neurologically, this behavioural repertoire clearly requires a neural system that is able to integrate the stimulus (the road) with a context (US or UK) to cue a behaviour (look left or look right). Current evidence suggests that neurons in the PFC appear to represent precisely this sort of information.^[citation needed] Other evidence from single-cell [electrophysiology](#) in monkeys implicates ventrolateral PFC (inferior prefrontal convexity) in the control of motor responses. For example, cells that increase their firing rate to NoGo signals^[74] as well as a signal that says "don't look there!"^[75] have been identified.

Attentional biasing in sensory regions

[Electrophysiology](#) and [functional neuroimaging](#) studies involving [human](#) subjects have been used to describe the neural mechanisms underlying attentional biasing. Most studies have looked for activation at the 'sites' of biasing, such as in the [visual](#) or [auditory cortices](#). Early studies employed [event-related potentials](#) to reveal that electrical brain responses recorded over left and right visual cortex are enhanced when the subject is instructed to attend to the appropriate (contralateral) side of space.^[76]

The advent of bloodflow-based neuroimaging techniques such as [functional magnetic resonance imaging](#) (fMRI) and [positron emission tomography](#) (PET) has more recently permitted the demonstration that neural activity in a number of sensory regions, including [color-](#), [motion-](#), and [face-responsive](#) regions of visual cortex, is enhanced when subjects are directed to attend to that dimension of a stimulus, suggestive of [gain control](#) in sensory

neocortex. For example, in a typical study, Liu and coworkers^[77] presented subjects with arrays of dots moving to the left or right, presented in either red or green. Preceding each stimulus, an instruction cue indicated whether subjects should respond on the basis of the colour or the direction of the dots. Even though colour and motion were present in all stimulus arrays, fMRI activity in [colour-sensitive regions](#) (V4) was enhanced when subjects were instructed to attend to the colour, and activity in [motion-sensitive regions](#) was increased when subjects were cued to attend to the direction of motion. Several studies have also reported evidence for the biasing signal prior to stimulus onset, with the observation that regions of the frontal cortex tend to come active prior to the onset of an expected stimulus.^[78]

Connectivity between the PFC and sensory regions

Despite the growing currency of the 'biasing' model of executive functions, direct evidence for functional connectivity between the PFC and sensory regions when executive functions are used, is to date rather sparse.^[79] Indeed, the only direct evidence comes from studies in which a portion of frontal cortex is damaged, and a corresponding effect is observed far from the lesion site, in the responses of sensory neurons.^{[80][81]} However, few studies have explored whether this effect is specific to situations where executive functions are required. Other methods for measuring connectivity between distant brain regions, such as correlation in the fMRI response, have yielded indirect evidence that the frontal cortex and sensory regions communicate during a variety of processes thought to engage executive functions, such as working memory,^[82] but more research is required to establish how information flows between the PFC and the rest of the brain when executive functions are used. As an early step in this direction, an fMRI study on the flow of information processing during visuospatial reasoning has provided evidence for causal associations (inferred from the temporal order of activity) between sensory-related activity in occipital and parietal cortices and activity in posterior and anterior PFC.^[83] Such approaches can further elucidate the distribution of processing between executive functions in PFC and the rest of the brain.

Bilingualism and executive functions

Main article: [Cognitive advantages of multilingualism](#)
[§ Executive function](#)

A growing body of research demonstrates that bilinguals might show advantages in executive functions, specifically inhibitory control and task switching.^{[84][85][86][page needed]} A possible explanation for this is that speaking two languages requires controlling one's attention and choosing the correct language to speak. Across development, bilingual infants,^[87] children,^[85] and elderly^[88] show a bilingual advantage when it comes to executive functioning. The advantage does not seem to manifest in younger adults.^[84] Bimodal bilinguals, or people who speak one oral language and one sign language, do not demonstrate this bilingual advantage in executive functioning tasks.^[89] This may be because one is not required to actively inhibit one language in order to speak the other. Bilingual individuals also seem to have an advantage in an area known as conflict processing, which occurs when there are multiple representations of one particular response (for example, a word in one language and its translation in the individual's other language).^[90] Specifically, the [lateral prefrontal cortex](#) has been shown to be involved with conflict processing. However, there are still some doubts. In a meta-analytic review, researchers concluded that bilingualism did not enhance executive functioning in adults.^[91]

In disease or disorder

The study of executive function in [Parkinson's disease](#) suggests subcortical areas such as the [amygdala](#), [hippocampus](#) and [basal ganglia](#) are important in these processes. [Dopamine](#) modulation of the prefrontal cortex is responsible for the efficacy of dopaminergic drugs on executive function, and gives rise to the [Yerkes Dodson Curve](#).^[92] The inverted U represents decreased executive functioning with excessive arousal (or increased catecholamine release during stress), and decreased executive functioning with insufficient arousal.^[93] The low activity polymorphism of [Catechol-O-methyltransferase](#) is associated with slight increase in performance on executive function tasks in healthy persons.^[94] Executive functions are impaired in multiple disorders including [anxiety disorder](#), [major depressive disorder](#), [bipolar disorder](#), [attention deficit hyperactivity disorder](#), [schizophrenia](#) and [autism](#).^[95] Lesions to the prefrontal cortex, such as in the case of [Phineas Gage](#), may also result in deficits of executive function. Damage to these areas may also manifest in deficits of other areas of function, such as [motivation](#), and [social functioning](#).^[96]

Future directions

Other important evidence for executive functions processes in the prefrontal cortex have been described. One widely cited review article^[97] emphasizes the role of the medial part of the PFC in situations where executive functions are likely to be engaged – for example, where it is important to detect errors, identify situations where stimulus conflict may arise, make decisions under uncertainty, or when a reduced probability of obtaining favourable performance outcomes is detected. This review, like many others,^[98] highlights interactions between [medial and lateral PFC](#), whereby posterior medial frontal cortex signals the need for increased executive functions and sends this signal on to areas in dorsolateral prefrontal cortex that actually implement control. Yet there has been no compelling evidence at all that this view is correct, and, indeed, one article showed that patients with lateral PFC damage had reduced ERNs (a putative sign of dorsomedial monitoring/error-feedback)^[99] – suggesting, if anything, that the direction of flow of the control could be in the reverse direction. Another prominent theory^[100] emphasises that interactions along the perpendicular axis of the frontal cortex, arguing that a 'cascade' of interactions between anterior PFC, dorsolateral PFC, and [premotor cortex](#) guides behaviour in accordance with past context, present context, and current sensorimotor associations, respectively.

Advances in [neuroimaging](#) techniques have allowed studies of genetic links to executive functions, with the goal of using the imaging techniques as potential [endophenotypes](#) for discovering the genetic causes of executive function.^[101]

More research is required to develop interventions that can improve executive functions and help people generalize those skills to daily activities and settings^[102]

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- Malenka, RC; Nestler, EJ; Hyman, SE (2009). "Chapter 6: Widely Projecting Systems: Monoamines, Acetylcholine, and Orexin". In Sydor, A; Brown, RY (eds.). *Molecular Neuropharmacology: A Foundation for Clinical Neuroscience* (2nd ed.). New York: McGraw-Hill Medical. pp. 155–157. [ISBN 978-0-07-148127-4](#). DA has multiple actions in the prefrontal cortex. It promotes the "cognitive control" of behavior: the selection and successful monitoring of behavior to facilitate attainment of chosen goals. Aspects of cognitive control in which DA plays a role include working memory, the ability to hold information "on line" in order to guide actions, suppression of prepotent behaviors that compete with goal-directed actions, and control of attention and thus the ability to overcome distractions. ... Noradrenergic projections from the LC thus interact with dopaminergic projections from the VTA to regulate cognitive control.

- • [Diamond, Adele \(2013\). "Executive functions". Annual Review of Psychology. 64: 135–168. doi:10.1146/annurev-psych-113011-143750. PMC 4084861. PMID 23020641.](#) Core EFs are inhibition [response inhibition (self-control—resisting temptations and resisting acting impulsively) and interference control (selective attention and cognitive inhibition)], working memory, and cognitive flexibility (including creatively thinking "outside the box," seeing anything from different perspectives, and quickly and flexibly adapting to changed circumstances). ... EFs and prefrontal cortex are the first to suffer, and suffer disproportionately, if something is not right in your life. They suffer first, and most, if you are stressed (Arnsten 1998, Liston et al. 2009, Oaten & Cheng 2005), sad (Hirt et al. 2008, von Hecker & Meiser 2005), lonely (Baumeister et al. 2002, Cacioppo & Patrick 2008, Campbell et al. 2006, Tun et al. 2012), sleep deprived (Barnes et al. 2012, Huang et al. 2007), or not physically fit (Best 2010, Chaddock et al. 2011, Hillman et al. 2008). Any of these can cause you to appear to have a disorder of EFs, such as ADHD, when you do not. You can see the deleterious effects of stress, sadness, loneliness, and lack of physical health or fitness at the physiological and neuroanatomical level in prefrontal cortex and at the behavioral level in worse EFs (poorer reasoning and problem solving, forgetting things, and impaired ability to exercise discipline and self-control). ... EFs can be improved (Diamond & Lee 2011, Klingberg 2010). ... At any age across the life cycle EFs can be improved, including in the elderly and in infants. There has been much work with excellent results on improving EFs in the elderly by improving physical fitness (Erickson & Kramer 2009, Voss et al. 2011) ... Inhibitory control (one of the core EFs) involves being able to control one's attention, behavior, thoughts, and/or emotions to override a strong internal predisposition or external lure, and instead do what's more appropriate or needed. Without inhibitory control we would be at the mercy of impulses, old habits of thought or action (conditioned responses), and/or stimuli in the environment that pull us this way or that. Thus, inhibitory control makes it possible for us to change and for us to choose how we react and how we behave rather than being unthinking creatures of habit. It doesn't make it easy. Indeed, we usually are creatures of habit and our behavior is under the control of environmental stimuli far more than we usually realize, but having the ability to exercise inhibitory control creates the possibility of change and choice. ... The subthalamic nucleus appears to play a critical role in preventing such impulsive or premature responding (Frank 2006).

[Figure 4: Executive functions and related terms](#)

- • Chan RC, Shum D, Touloupoulou T, Chen EY (March 2008). "Assessment of executive functions: review of instruments and identification of critical issues". *Archives of Clinical Neuropsychology*. 23 (2): 201–216. doi:10.1016/j.acn.2007.08.010. PMID 18096360. The term "executive functions" is an umbrella term comprising a wide range of cognitive processes and behavioral competencies which include verbal reasoning, problem-solving, planning, sequencing, the ability to sustain attention, resistance to interference, utilization of feedback, multitasking, cognitive flexibility, and the ability to deal with novelty (Burgess, Veitch, de lacy Costello, & Shallice, 2000; Damasio, 1995; Grafman & Litvan, 1999; Shallice, 1988; Stuss & Benson, 1986; Stuss, Shallice, Alexander, & Picton, 1995).
- • Washburn, DA (2016). "The Stroop effect at 80: The competition between stimulus control and cognitive control". *J Exp Anal Behav*. 105 (1): 3–13. doi:10.1002/jeab.194. PMID 26781048. Today, arguably more than at any time in history, the constructs of attention, executive functioning, and cognitive control seem to be pervasive and preeminent in research and theory. Even within the cognitive framework, however, there has long been an understanding that behavior is multiply determined, and that many responses are relatively automatic, unattended, contention-scheduled, and habitual. Indeed, the cognitive flexibility, response inhibition, and self-regulation that appear to be hallmarks of cognitive control are noteworthy only in contrast to responses that are relatively rigid, associative, and involuntary.
- • Alvarez, Julie A.; Emory, Eugene (2006). "Executive function and the frontal lobes: A meta-analytic review". *Neuropsychology Review*. 16 (1): 17–42. doi:10.1007/s11065-006-9002-x. PMID 16794878.
- • Malenka, RC; Nestler, EJ; Hyman, SE (2009). "Chapter 13: Higher Cognitive Function and Behavioral Control". In Sydor, A; Brown, RY (eds.). *Molecular Neuropharmacology: A Foundation for Clinical Neuroscience (2nd ed.)*. New York: McGraw-Hill Medical. p. 315. ISBN 978-0-07-148127-4. However, damage to the prefrontal cortex has a significant deleterious effect on social behavior, decision making, and adaptive responding to the changing circumstances of life. ... Several subregions of the prefrontal cortex have been implicated in partly distinct aspects of cognitive control, although these distinctions remain somewhat vaguely defined. The anterior cingulate cortex is involved in processes that require correct decision-making, as seen in conflict resolution (eg, the Stroop test, see in Chapter 16), or cortical inhibition (eg, stopping one task and switching to another). The medial prefrontal cortex is

involved in supervisory attentional functions (eg, action-outcome rules) and behavioral flexibility (the ability to switch strategies). The dorsolateral prefrontal cortex, the last brain area to undergo myelination during development in late adolescence, is implicated in matching sensory inputs with planned motor responses. The ventromedial prefrontal cortex seems to regulate social cognition, including empathy. The orbitofrontal cortex is involved in social decision making and in representing the valuations assigned to different experiences.

- • Malenka, RC; Nestler, EJ; Hyman, SE (2009). "Chapter 13: Higher Cognitive Function and Behavioral Control". In Sydor, A; Brown, RY (eds.). *Molecular Neuropharmacology: A Foundation for Clinical Neuroscience* (2nd ed.). New York: McGraw-Hill Medical. pp. 313–321. [ISBN 978-0-07-148127-4](#). • Executive function, the cognitive control of behavior, depends on the prefrontal cortex, which is highly developed in higher primates and especially humans.

- Working memory is a short-term, capacity-limited cognitive buffer that stores information and permits its manipulation to guide decision-making and behavior. ...

These diverse inputs and back projections to both cortical and subcortical structures put the prefrontal cortex in a position to exert what is often called "top-down" control or cognitive control of behavior. ... The prefrontal cortex receives inputs not only from other cortical regions, including association cortex, but also, via the thalamus, inputs from subcortical structures subserving emotion and motivation, such as the amygdala (Chapter 14) and ventral striatum (or nucleus accumbens; Chapter 15). ...

In conditions in which prepotent responses tend to dominate behavior, such as in drug addiction, where drug cues can elicit drug seeking (Chapter 15), or in attention deficit hyperactivity disorder (ADHD; described below), significant negative consequences can result. ... ADHD can be conceptualized as a disorder of executive function; specifically, ADHD is characterized by reduced ability to exert and maintain cognitive control of behavior. Compared with healthy individuals, those with ADHD have diminished ability to suppress inappropriate prepotent responses to stimuli (impaired response inhibition) and diminished ability to inhibit responses to irrelevant stimuli (impaired interference suppression). ... Functional neuroimaging in humans demonstrates activation of the prefrontal cortex and caudate nucleus (part of the striatum) in tasks that demand inhibitory control of behavior. Subjects with ADHD exhibit less activation of the medial prefrontal cortex than healthy controls even when they succeed in such tasks and utilize different circuits. ... Early results with structural MRI show thinning of the cerebral cortex in ADHD subjects compared with age-matched controls in prefrontal cortex and posterior parietal cortex, areas involved in working memory and attention.

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Executive Function & Self-Regulation

Content in This Guide

Step 1: Executive Function 101

- **You Are Here:** Executive Function & Self-Regulation (
- [Executive Function: Skills for Life and Learning](#) **Step 2: The Science of Executive Function**
Step 3: Building Executive Function Skills (Executive function and self-regulation skills are the mental processes that enable us to plan, focus attention, remember instructions, and juggle multiple tasks successfully. Just as an air traffic control system at a busy airport safely manages the arrivals and departures of many aircraft on multiple runways, the brain needs this skill set to filter distractions, prioritize tasks, set and achieve goals, and control impulses. **(When children have opportunities to develop executive function and self-regulation skills, individuals and society experience lifelong benefits.** These skills are crucial for learning and development. They also enable positive behavior and allow us to make healthy choices for ourselves and our families. **(Executive function and self-regulation skills depend on three types of brain function: working memory, mental flexibility, and self-control.** These functions are highly interrelated, and the successful application of executive function skills requires them to operate in coordination with each other. (Each type of executive function skill draws on elements of the others. (
- **Working memory** governs our ability to retain and manipulate distinct pieces of information over short periods of time. (
- **Mental flexibility** helps us to sustain or shift attention in response to different demands or to apply different rules in different settings. (
- **Self-control** enables us to set priorities and resist impulsive actions or responses. **(Children aren't born with these skills—they are born with the potential to develop them.** If children do not get what they need from their relationships with adults and the conditions in their environments—or (worse) if those influences are sources of [toxic stress](#)—their skill development can be seriously delayed or impaired. Adverse environments resulting from [neglect](#), abuse, and/or violence may expose children to toxic stress, which disrupts [brain architecture](#) and impairs the development of executive function. (By focusing on real-life daily situations such as bedtime and mealtime, the [Ready4Routines](#) intervention seeks to strengthen executive function skills in adults and children, while also increasing predictability within young children's lives. **(Providing the support that children need to build these skills at home, in early care and education programs, and in other settings they experience regularly is one of society's most important responsibilities.**

Growth-promoting environments provide children with “scaffolding” that helps them (

practice necessary skills before they must perform them alone. Adults can facilitate the development of a child’s executive function skills by establishing routines, modeling social behavior, and creating and maintaining supportive, reliable relationships. It is also important for children to exercise their developing skills through activities that foster creative play and social connection, teach them how to cope with stress, involve vigorous exercise, and over time, provide opportunities for directing their own actions with decreasing adult supervision.

Building the Core Skills Youth Need for Life

A Guide for Education and
Social Service Practitioners



All youth need to develop a set of **core life skills** to manage school, work, outside interests, and social relationships successfully. From the perspective of brain development, these skills include **planning, focus, self-control, awareness, and flexibility**—also known as “executive function” and “self-regulation” skills. No one is born with these skills, but everyone can learn them through practice.

Core Life Skills

PLANNING

Being able to make concrete plans, carry them out, and set and meet goals

What Happens in the Brain When We Feel Fear

And why some of us just can't get enough of it



Scary pumpkins are the least of what frightens us at Halloween, a day devoted to being frightened. (asife/Shutterstock.com)

By Arash Javanbakht and Linda Saab, [The Conversation](#)
smithsonian.com

October 27, 2017

Fear may be as old as life on Earth. It is a fundamental, deeply wired reaction, evolved over the history of biology, to protect organisms against perceived threat to their integrity or existence. Fear may be as simple as a cringe of an antenna in a snail that is touched, or as complex as existential anxiety in a human.

Whether we love or hate to experience fear, it's hard to deny that we certainly revere it – devoting an entire holiday to the celebration of fear.

Thinking about the circuitry of the brain and human psychology, some of the main chemicals that contribute to the “fight or flight” response are also involved in other positive emotional states, such as happiness and excitement. So, it makes sense that the high arousal state we experience during a scare may also be experienced in a more positive light. But what makes the difference between getting a “rush” and feeling completely terrorized?

We are psychiatrists who treat fear and study its neurobiology. Our studies and clinical interactions, as well as those of others, suggest that a major factor in how we experience fear has

to do with the [context](#). When our “thinking” brain gives feedback to our “emotional” brain and we perceive ourselves as being in a safe space, we can then quickly shift the way we experience that high arousal state, going from one of fear to one of enjoyment or excitement.

When you enter a haunted house during Halloween season, for example, anticipating a ghoul jumping out at you and knowing it isn’t really a threat, you are able to quickly relabel the experience. In contrast, if you were walking in a dark alley at night and a stranger began chasing you, both your emotional and thinking areas of the brain would be in agreement that the situation is dangerous, and it’s time to flee!

But how does your brain do this?

Fear reaction starts in the brain and spreads through the body to make adjustments for the best defense, or flight reaction. The fear response starts in a region of the brain called the [amygdala](#). This almond-shaped set of nuclei in the temporal lobe of the brain is dedicated to detecting the emotional salience of the stimuli – how much something stands out to us.

For example, the amygdala activates whenever we see a human face with an emotion. This reaction is more pronounced with anger and fear. A threat stimulus, such as the sight of a predator, triggers a fear response in the amygdala, which activates areas involved in preparation for motor functions involved in fight or flight. It also triggers release of stress hormones and sympathetic nervous system.

This leads to [bodily changes](#) that prepare us to be more efficient in a danger: The brain becomes hyperalert, pupils dilate, the bronchi dilate and breathing accelerates. Heart rate and blood pressure rise. Blood flow and stream of glucose to the skeletal muscles increase. Organs not vital in survival such as the gastrointestinal system slow down.

A part of the brain called the hippocampus is closely connected with the amygdala. The hippocampus and prefrontal cortex help the brain interpret the perceived threat. They are involved in a higher-level processing of context, which helps a person know whether a perceived threat is real.

For instance, seeing a lion in the wild can trigger a strong fear reaction, but the response to a view of the same lion at a zoo is more of curiosity and thinking that the lion is cute. This is because the hippocampus and the frontal cortex process contextual information, and inhibitory pathways dampen the amygdala fear response and its downstream results. Basically, our “thinking” circuitry of brain reassures our “emotional” areas that we are, in fact, OK.



Being attacked by a dog or seeing someone else attacked by a dog triggers fear. (Jaromir Chalabala/Shutterstock.com)

Similar to other animals, we very [often learn fear](#) through personal experiences, such as being attacked by an aggressive dog, or observing other humans being attacked by an aggressive dog.

However, an evolutionarily unique and fascinating way of learning in humans is through instruction – we [learn from the spoken words](#) or written notes! If a sign says the dog is dangerous, proximity to the dog will trigger a fear response.

We learn safety in a similar fashion: experiencing a domesticated dog, observing other people safely interact with that dog or reading a sign that the dog is friendly.

Fear creates distraction, which can be a positive experience. When something scary happens, in that moment, we are on high alert and not preoccupied with other things that might be on our mind (getting in trouble at work, worrying about a big test the next day), which brings us to the here and now.

Furthermore, when we experience these frightening things with the people in our lives, we often find that emotions can be contagious in a positive way. We are social creatures, able to learn from one another. So, when you look over to your friend at the haunted house and she's quickly gone from screaming to laughing, socially you're able to pick up on her emotional state, which can positively influence your own.

While each of these factors - context, distraction, social learning - have potential to influence the way we experience fear, a common theme that connects all of them is our sense of control. When we are able to recognize what is and isn't a real threat, relabel an experience and enjoy the thrill of that moment, we are ultimately at a place where we feel in control. That perception of control is vital to how we experience and respond to fear. When we overcome the initial "fight or flight" rush, we are often left feeling satisfied, reassured of our safety and more confident in our ability to confront the things that initially scared us.

It is important to keep in mind that everyone is different, with a unique sense of what we find scary or enjoyable. This raises yet another question: While many can enjoy a good fright, why might others downright hate it?

Any imbalance between excitement caused by fear in the animal brain and the sense of control in the contextual human brain may cause too much, or not enough, excitement. If the individual perceives the experience as "too real," an extreme fear response can overcome the sense of control over the situation.

This may happen even in those who do love scary experiences: They may enjoy [Freddy Krueger](#) movies but be too terrified by "[The Exorcist](#)," as it feels too real, and fear response is not modulated by the cortical brain.

On the other hand, if the experience is not triggering enough to the emotional brain, or if is too unreal to the thinking cognitive brain, the experience can end up feeling boring. A biologist who cannot tune down her cognitive brain from analyzing all the bodily things that are realistically impossible in a zombie movie may not be able to enjoy "[The Walking Dead](#)" as much as another person.

So if the emotional brain is too terrified and the cognitive brain helpless, or if the emotional brain is bored and the cognitive brain is too suppressing, scary movies and experiences may not be as fun.

All fun aside, abnormal levels of fear and anxiety can lead to significant distress and dysfunction and limit a person's ability for success and joy of life. Nearly one in four people experiences a form of [anxiety disorder](#) during their lives, and nearly 8 percent experience post-traumatic stress disorder (PTSD).

Disorders of anxiety and fear include phobias, social phobia, generalized anxiety disorder, separation anxiety, PTSD and obsessive compulsive disorder. These conditions usually begin at a young age, and without appropriate treatment can become chronic and debilitating and affect a person's life trajectory. The good news is that we have effective treatments that work in a relatively short time period, in the form of psychotherapy and medications.

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