


# Attention and self-control: self-regulation from the bottom up

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## ABSTRACT

According to a widespread view, self-control is a top-down cognitive process that downregulates bottom-up processes, where those bottom-up processes, unless downregulated, are detrimental to self-control. In this paper, I argue that thinking of self-control solely in terms of top-down cognitive control is misleading. Instead, self-control has a necessary bottom-up component in conflict detection, realized by the interplay of the ventral attention circuit and the anterior cingulate cortex. This mechanism generalizes across different forms of self-control. I describe a model of the roles of top-down and bottom-up processing in self-control where bottom-up conflict detection allows the emergence of top-down control. On this model, some cases of self-control failure that are standardly thought to indicate impaired top-down control may often instead reflect maladaptive conflict detection. This insight also carries clinical relevance, such as for understanding ADHD. Intriguingly, this makes self-control begin nonvolitionally. Yet, while agents cannot exert synchronic control over whether conflict detection occurs, they can attempt to facilitate it through diachronic self-regulation, such as by shaping their circumstances to better enable adaptive conflict detection.

## 1. Introduction

Self-control helps us align our behavior with the course of action we have committed to in the face of occurrent or anticipated motivational conflict. One might need it when trying to hold one's tongue in a family quarrel, when trying to conform to a diabetes-friendly diet but hankering for ice cream, and when one has committed to spending the afternoon writing but would like to hit the beach instead.

Research into self-control across psychology, philosophy, and the cognitive and neurosciences, can be branched into two interconnected streams of inquiry. Some researchers seek to understand the processes and mechanisms by which self-control is realized, explicating what happens when self-control is deployed or when it fails (Ainslie, 2001, 2021; Baumeister et al., 2007, 2024; Duckworth et al., 2016; Koi, 2023; Sripada, 2021). Others are interested in individual differences in self-control, as it appears that some people are better at controlling themselves than others (Baumeister et al., 2019; De Ridder et al., 2012; Gillebaart & de Ridder, 2015; Haug, 2021; Bwalya et al., 2026). In that strand of research, self-control is construed of as a trait. This contrast is often drawn in terms of 'state' versus 'trait' self-control (de Ridder et al., 2018; Inzlicht & Roberts, 2024; Napolitano et al., 2024). Here, I refer to 'process' rather than 'state' self-control because 'process' more aptly captures the structure of instances of self-control (Sripada, 2021),

unfolding over time and involving multiple cognitive states.

These research trajectories inform each other: the 'processes and mechanisms' strand of inquiry might also help us understand how individual differences in self-control emerge, and vice versa. Ultimately, however, their explanandum is different. In this paper, my primary concern is the processes and mechanisms by which self-control is realized.

Understanding self-control is also of clinical significance. For example, Attention-deficit/hyperactivity disorder (ADHD) is often dubbed a disorder of self-control (Barkley, 1997), and difficulties in cognitive control and self-control can also present in many other diagnoses, including e.g. bipolar disorder and schizophrenia (McTeague et al., 2017; Victor et al., 2011; Voss et al., 2017).

In research that seeks to explicate self-control as a process, while the specifics are under some debate, self-control is seen essentially as a *top-down* process (Duckworth et al., 2016; Sripada, 2021). The distinction between top-down and bottom-up processes in action regulation is central to cognitive psychology and related disciplines. While definitions vary, in broad strokes, top-down action regulation involves the coordination of action through processes largely associated with the prefrontal cortex (Roepstorff & Frith, 2004) that coordinate and modulate other neurocognitive processes, reflecting volitional motivational states (Miller & D'Esposito, 2005) such as intentions, goals, and

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choices (Wallace, 1999). Bottom-up processes by contrast arise independently of volition. The paradigmatic case is processes that arise in response to external stimuli (Roepstorff & Frith, 2004), but these also include internally generated processes, such as spontaneous thought, that can arise due to endogenous signals of error, conflict, or uncertainty (Beldzik et al., 2022; Christoff et al., 2009), default mode network dynamics (Andrews-Hanna et al., 2014) and interoceptive signals (Barrett & Simmons, 2015).

On a widely held conception, self-control is taken to entail the willed regulation of behavior by the self, i.e., by something that is at the figurative ‘top’ of cognition. This conception is often specified in terms of cognitive control: the view is that self-control is the top-down regulation of behavior by means of cognitive control. In contemporary research on how subsystems of the brain contribute to behavior regulation, the terms ‘cognitive control’, ‘executive functioning’ and ‘central executive’ are often used synonymously: each of these refers to systems or processes by which psychological sub-systems are regulated such that complex tasks such as decision-making or self-control can be accomplished, involving neural processes across multiple areas of the brain, but most prominently the prefrontal cortex (Cohen, 2017; Friedman & Robbins, 2022). Meanwhile, cognitive control may not be a discrete, unified kind (Cohen, 2017). In what follows, I use ‘cognitive control’ as a general term to refer to the set of neurocognitive processes and mechanisms that allows us to influence, organize and monitor complex behavior.

The notion of top-down processing is not without its critics. First, the idea of top-down cognition elicits the connotation that *some* part of our neural or cognitive makeup, such as the central executive system, makes decisions to regulate the rest – which veers dangerously in the territory of positing a homunculus (Baddeley, 1996; Dennett, 1978; Roepstorff & Frith, 2004). This follows influential criticisms by Daniel Dennett (Dennett, 1978), who predicted that further scientific inquiry will result in a deflation of the concept of cognitive control, where supposed top-down regulation “is itself broken down into subcomponents that are themselves clearly just unconscious underlaborers” (Dennett, 1978, p. 124). However, contemporary research on the central executive system is able to avoid the standard ‘homunculus’ criticisms. As Denis Buehler argues, the central executive is not a homunculus in the sense of possessing the cognitive capacities of the human individual: it does not reason or make decisions. Instead, it coordinates the deployment of a range of psychological sub-systems so that complex tasks such as decision-making can be accomplished (Buehler, 2018).

While this response addresses the concern that talk of top-down executive function would posit a homunculus, it bites the bullet with regard to Dennett’s prediction that this would reduce supposed top-down control to a set of bottom-up processes. But, cognitive control is generally taken to support (Berkman, 2017) or constitute (Sripada, 2021) self-control precisely because it is taken to reflect willed top-down processing! The worry is, if bottom-up, nonvolitional processes are all there is to self-control, we face what philosophers term the problem of the disappearing agent. The concern here is that “psychological and physiological events take place inside a person, but the person serves merely as the arena for these events: he takes no active part” (Velleman, 1992, p. 461). As a result, bottom-up processes that guide behavior, such as impulses, affects, and prepotent responses, are often thought to be detrimental to agency and therefore the very thing that self-control is supposed to downregulate (Loewenstein & Carbone, 2024; Rigoni et al., 2012; Sripada, 2021).

Secondly, as a family of approaches to situated cognition, including ecological psychology, predictive processing approaches, and enactivist frameworks of cognition emphasise, there are unlikely to be purely top-down processes. Instead, stimulus-driven aspects factor in much of cognition, including the processes of self-control and choice that are usually taken to be endogenous and volitional (Waal & Ferrari, 2010). Behavior is seen as a downstream effect of the interplay of top-down and bottom-up processes where these cannot be fully separated (Gallagher &

Allen, 2018). This picture need not rule out a meaningful account of cognitive control but suggests that construing it solely in terms of top-down regulation may mislead.

Even if not separable, there is ample evidence that bottom-up and top-down processes are distinct. In particular, in the study of attention, two neural circuits for attention have been identified. The dorsal attentional circuit regulates top-down attention based on prior knowledge, choice, and plans (Fox et al., 2006; Vossel et al., 2014). The ventral attentional circuit, by contrast, regulates the direction of attention to sensory input based on the properties of the stimulus: for example, when we hear a loud bang or stub our toe, that sensory input captures our attention, irrespective of our planning agency (Katsuki & Constantinidis, 2014). The neural pathways involved in bottom-up versus top-down attention are different, although they overlap: the frontoparietal network is an essential component of both (Connor et al., 2004; Katsuki & Constantinidis, 2014). Further, while the dorsal and ventral attentional circuits are both structurally and functionally distinct (Alves et al., 2022; Connor et al., 2004; Fox et al., 2006), their flexible interaction is needed for adaptive behavior (Ahrens et al., 2019; Vossel et al., 2014).

In this article, I argue that thinking of self-control solely in terms of top-down cognitive control is misleading. Likewise misguided is the notion that bottom-up processes would be detrimental to self-control. Instead, I suggest self-control has a necessary bottom-up component in conflict detection (Botvinick et al., 2001; Walsh et al., 2011). If we take action to entail active guidance (Buehler, 2023; Frankfurt, 1997; Velleman, 1992), this makes self-control begin non-actionally. I describe a model of the roles of top-down and bottom-up processing in self-control where bottom-up conflict detection allows the emergence of top-down control. While agents cannot exert synchronic control over whether or not conflict detection occurs, they can facilitate it through diachronic self-regulation, such as by shaping their circumstances to better enable conflict detection.

This article proceeds by follows. To locate the contribution in the relevant literature, I first examine the heterogeneous forms that top-down self-control can take, in Section 2. There is tension between lines of research emphasizing the diversity of self-control strategies, and others that seek unifying cognitive mechanisms. To identify where these approaches might converge, in Section 3, I consider the relationship between attention and cognitive control, focusing on the distinct roles of the ventral and dorsal attention streams. Building on these foundations, Section 4 lays out the main novel contribution of the paper, arguing that conflict detection constitutes a bottom-up mechanism necessary for self-control. I then explore the implications of this view for understanding individual differences in self-control, including those observed in ADHD, in Section 5. Finally, to address concerns that the bottom-up nature of conflict detection would render agents powerless over their capacity for self-control, Section 6 proposes that agents can indirectly influence future conflict detection and presents a schematic model illustrating the dynamics of this process.

## 2. Heterogeneity in top-down self-control

Top-down self-control has motivated a substantial research program. Yet perhaps the most striking feature of self-control, as discussed in the work of Walter Mischel and colleagues (Mischel & Ebbsen, 1970, 1977; Metcalfe & Mischel 1999) and in the subsequent boom of research into the various correlates of individual differences in self-control (Casey et al., 2011; Duckworth et al., 2016), is the heterogeneity of strategies that people use to self-regulate. On Duckworth et al.’s (2016) taxonomy, these strategies include intrapsychic strategies, such as response modulation, self-distraction, and cognitive change (e.g., framing), as well as situational strategies like situation selection, such as when a student goes to the library to study in order to avoid the temptation to play console games instead, situation modification, which includes modulating one’s physical environment, such as when a student hides the game console and puts the textbook in plain view, and social strategies,

such as asking friends to police one's smoking.

While defenders of functionalist conceptions of self-control (Duckworth et al., 2016; Koi, 2021, 2023; Levy, 2017; Mele, 1987, 1995; Vierkant, 2015) embrace this heterogeneity, others have raised concerns about it. A prominent critic of functionalist views of self-control, Chandra Sripada (Sripada, 2021), terms the anti-functionalist approach the 'process' view. On the process account, what makes something count as self-control is the underlying cognitive process, which should then be unified across different cases of self-control, whether the cases in question concern trying not to scratch an itch or holding one's tongue in a family quarrel. By contrast, on his terminology, functionalist views are 'results' views: whatever yields the desired result of self-control – that of aligning behavior with intention despite motivational conflict – counts as self-control. The startling heterogeneity of strategies that get the job of self-control done is worrisome for proponents of 'process' views, because it is hard, if not downright impossible, to find unifying, nontrivial cognitive processes or mechanisms for behaviors so heterogeneous (Herdova, 2017). In section 4, I will suggest a mechanism that generalizes across these heterogeneous behaviors. But before that, it is helpful to see how prior candidates for mechanistically unifying or explicating self-control have fared.

Ego depletion theory was once a prominent candidate for a mechanistic theory of self-control. According to it, top-down self-control relied on a dedicated cognitive resource which depleted in use (Baumeister et al., 2007, 2018, 2024). However, the theory has faced an onslaught of conceptual and empirical problems (Dang & Hagger, 2019; Hagger et al., 2016; Inzlicht & Friese, 2019; Job et al., 2010; Levy, 2011; Vadillo et al., 2016; Vohs et al., 2021): what initially seemed like evidence for the depletion of the self-control resource's reserves has turned out to be hard to distinguish from the general effect of fatigue on cognition. Current candidates for top-down processes or mechanisms of self-control include mechanisms of cognitive control (Irving et al., 2022; Sripada, 2021) and inhibition (Brass & Haggard, 2007; Cohen et al., 2013; Muraven et al., 2006). While it is uncontroversial that inhibition plays a role across many self-control processes, it is ill suited to the unificatory task because it is neither *specific* to self-control nor *general* to all self-control. It is not specific to self-control because processes of inhibition are part and parcel of much skilled action and social cognition (Amici et al., 2018; Buehler, 2021; Fujita, 2011; Gray, 2009). This is unsurprising given that complex psychological processes share neurocognitive mechanisms (Duncan, 2010; Panichello & Buschman, 2021). And, it is not general to all self-control as sometimes we seem to deploy self-control to *initiate* a behavior, rather than to stop ourselves from engaging in one. Note also that inhibitory control tasks in the laboratory display limited test-retest reliability (Schuch et al., 2022) and have limited value for predicting self-control success outside of the laboratory (Duckworth & Kern, 2011; Hedge et al., 2018; Schuch et al., 2022), suggesting that while the inhibitory control construct may have some utility, self-control success is not contingent on it alone.

Finally, while inhibition is involved in many instances of self-control, it might not be the right sort of construct for describing a unified process. Work by Friedman & Miyake suggested that what had previously been construed as a single inhibitory capacity instead appears to be a family of competencies (Friedman & Miyake, 2004; Miyake et al., 2000; Miyake & Friedman, 2012). Werner and colleagues have suggested that inhibition is itself realized by multiple, divergent neurocognitive processes: on their account, the inhibition construct refers to a state, not to a process or mechanism (Werner et al., 2022). If they are correct, then appeals to inhibition turn out to not describe a single process unless qualified further.

Another candidate construct to be deployed here is cognitive control. If cognitive control is general to self-control, and if cognitive control is a unified process, then appealing to cognitive control would give us a way to unify self-control as a process. As mentioned above, broadly defined, cognitive control is the set of processes that allows us to influence, organize and monitor our behavior; this set includes inhibition (Badre,

2022). As such, cognitive control is clearly general to all self-control, but again not dedicated to it. Still, some have endeavored to create a unified mechanistic account of self-control by appealing to cognitive control further qualified. A prominent contribution to the philosophical literature on self-control by Chandra Sripada (Sripada, 2021) articulates such a qualified account. Sripada fleshes out his account as follows: a motivational state, such as an emotion, impulse or craving, produces what Sripada terms 'response pulses', which bias action selection. Importantly, while a 'response pulse' is brief, only hundreds of milliseconds in duration, motivational states – which last longer – produce extended streams of these. Cognitive control is then used to downregulate response pulses. Self-control is the occurrent deployment of cognitive control for this purpose in a skilled, sustained, and effortful way. (Sripada, 2021).

Sripada's rich account deserves more scrutiny than I have space for here (for discussion, see Koi, 2023). In particular, the 'response pulse' construct would merit further inquiry: while it could help articulate theories of cognitive control beyond the self-control debate, it has not yet been substantially scrutinized. To draw out the stakes of the debate, I want to focus on what Sripada's account rules out. If his account is correct, then some putative self-control strategies, namely ones that remove the need for occurrent downregulation of wayward response pulses, turn out not to be self-control at all. These would include many of the strategies deployed by successful delayers of gratification in the Stanford studies on delayed gratification, colloquially referred to as the 'marshmallow experiments' (Mischel & Ebbesen, 1970). For example, children who occupied themselves with singing, playing, or even falling asleep avoided the need to deploy a skilled, sustained, and effortful sequence of control actions to downregulate response pulses biasing them in favor of eating the marshmallow. Yet these strategies turned out to be very effective for delayed gratification, and teaching the skill of self-control entailed teaching just these strategies (Bermúdez, 2021; Duckworth et al., 2016; Levy, 2017; Mischel & Ebbesen, 1970; Mischel et al., 1989, 2011; Tang et al., 2022). Of course, steering oneself to engage in these pre-emptive strategies itself takes cognitive control, but that control sequence need not be co-occurrent with the wayward motivational state and its resultant response pulses, and hence falls outside Sripada's definition of self-control.

Ultimately, then, Sripada's account can unify self-control only if we are willing to restrict the self-control construct to cases where occurrent effortful downregulation of response pulses occurs. Accepting such an account entails the paradoxical conclusion that those high in trait self-control, i.e. those who are good at deploying self-control strategies, use less self-control than others (Bermúdez, 2021; Haug, 2021, 2022; Levy, 2017). Sripada and colleagues make the case that we should be willing to accept these consequences because this harmonizes with lay conceptions of self-control (Irving et al., 2022; Sripada, 2021). Arguing against this approach, Koi (2024) argues that lay conceptions themselves have been shaped by historical and cultural trends that have driven an association between self-control and the metaphor of 'will-power', the metaphor guiding us to think of self-control in terms of occurrent effort, and therefore aligning our definitions of self-control with lay conceptions may yield a definition with limited utility for scientific and philosophical inquiry. Concurrently, perspectives in the cognitive neuropsychology of cognitive control have emerged that criticize the assumption that control must be effortful (Tang et al., 2022).

While I have focused on Sripada's account above, other accounts that associate self-control with cognitive control further qualified face similar limitations insofar as they exclude certain strategies of self-control that make use of situation modification and situational constraints, social support, construal, or the temporal dynamics of motivation.

The above discussion highlights how psychological and philosophical theory has sought to explicate self-control in terms of top-down processes alone, describing such processes either in terms of cognitive

control or, on the functionalist view, as a heterogeneous set of strategies. For the purposes of this paper, the debate concerning whether strategies constitute self-control need not be resolved. Instead, in what follows, I want to focus on an upstream mechanism of self-control that has received sparse attention in the theoretical literature, namely, conflict monitoring. As I will argue, while functionalist views contest the necessity of occurrent cognitive control for self-control, they must grant antecedent conflict monitoring to be necessary.

### 3. Attention and cognitive control

Attention can be broadly defined as the set of cognitive mechanisms that selectively prioritize certain pieces of information for further processing while filtering out others (Chun et al., 2011; Watzl, 2017, 2022). Through this prioritization, attentional processes shape and simplify the task space, making it more manageable and available for action selection for cognitively bounded agents (Wu, 2011, 2023). Consequently, attention and cognitive control are closely intertwined, and the precise nature of their relationship remains under investigation. In this section, I will discuss how distinguishing between bottom-up and top-down attention can help us better understand the relationship of attention and cognitive control, allowing us to articulate what bottom-up attention's role in self-control is.

A role for attention in cognitive control is suggested, e.g., in resource models of cognitive control, and models of cognitive control based on limited cognitive bandwidth (Cohen, 2017; Mittner et al., 2016). Another way to articulate the relationship between attention and cognitive control is to point to the agential nature of attention. On accounts emphasizing attention's agential aspects, attention selects or prioritizes information for the purposes of action (Wu, 2011, 2023), or else, attending itself is a mental activity (Buehler, 2023; Watzl, 2017) where shifts in attention steer our behavior.

While much hinges on the specific conceptions of attention and cognitive control being deployed, theorists must also reckon with the difficulty of disentangling attention and cognitive control in experimental settings (Bugg, 2012). For instance, although the Stroop task is widely employed to investigate cognitive control, it was originally designed to measure interference from irrelevant information (Stroop, 1935), which is a hallmark of selective attention.

From the perspective of systems neuroscience, there is convergent evidence that two distinct but interacting systems of the brain support attention: the dorsal and ventral attention networks (Alves et al., 2022; Corbetta et al., 2000; Sani et al., 2021; Shine et al., 2014; Vossel et al., 2014). Most evidence on these networks is in the context of visual attention, but there is also some indication that they may integrate multisensory input (Macaluso, 2010; Tang et al., 2016). Put briefly, agents may intentionally direct their attention (Buehler, 2023), a process facilitated by the dorsal attention network. This network is primarily involved in top-down, goal-directed allocation of attention. It enables us to focus selectively on task-relevant information, consistent with the broader notion of selective attention guided by cognitive control. But attention can also be directed nonvolitionally, such as to surprising or prominent stimuli, by the ventral attention network (Vossel et al., 2014). Rather than reflecting top-down guidance of attention, the ventral attention network is recruited for the rapid orienting of attention toward unexpected or salient events in the environment (Bowling et al., 2019; Shine et al., 2014) or endogenous signals (Barrett & Simmons, 2015; Christoff et al., 2009). Importantly, however, while it's characteristic of dorsal attention to be under top-down guidance and for ventral attention to be automatic, these ought not to be taken as absolute. Instead, both dorsal and ventral attention can be either automatic or goal-oriented (Wu, 2025), and the systems interact flexibly, often operating together.

The two attention networks were first suggested as operating independently (Corbetta & Shulman, 2002), but we now know their function involves flexible interaction (Vossel et al., 2014). Still, while interacting,

the two networks differ from each other not just functionally, but also anatomically and neurochemically (Alves et al., 2022; Vossel et al., 2014). Anatomically, the dorsal network includes regions such as the frontal eye fields, dorsolateral prefrontal cortex, and posterior parietal cortex. The ventral network, by comparison, engages structures such as the temporoparietal junction, the ventral frontal cortex, anterior cingulate cortex and anterior insula, among others (Shine et al., 2014; Vossel et al., 2014). Both also include subcortical structures, such as nuclei of the brainstem (Alves et al., 2022).

The dorsal attention system and cognitive control are closely associated (Buehler, 2023; Dixon et al., 2017, 2018; Jennings, 2022; Rosen et al., 2016). For self-control, active strategies that regulate our behavior by regulating dorsal attention, such as when we avoid temptation by shifting our attention away from the temptation, are perhaps the most documented self-control strategy, having been identified already in the Stanford experiments on delayed gratification in children (Duckworth et al., 2016; Mischel & Ebbsen, 1970).

Meanwhile, the relationship of ventral attention and self-control is scarcely discussed. This is surprising given that it's ubiquitously recognized, though rarely emphasized, that conflict monitoring is required for self-control to occur (see, e.g., Kotabe & Hofmann, 2015). That is, agents cannot deploy self-control to regulate behavior in response to a motivational conflict unless an occurrent or expected conflict is detected. Despite this being common knowledge, theorizing about self-control has not substantially considered its implications for the relationship of ventral attention and self-control.

Conflict detection requires monitoring, which is largely accomplished by the ventral rather than dorsal attention system (Langner & Eickhoff, 2013). Here, the ventral attention system allows for flexible adjustment of behavior in response to environmental stimuli, which it registers. Conflict detection occurs when responding to the stimulus is processed as at odds with occurrent or planned behavior: for example, a fire alarm captures a writer's attention, and a conflict is detected – performing fire safety procedures conflicts with writing away on one's laptop. This monitoring is tacit and relatively independent of dorsal attention. Even when focusing one's (dorsal) attention on writing, the ventral system monitors the environment for relevant stimuli such as fire alarms.

Importantly, task-incongruent signals need not be external stimuli. Instead, they may be internal signals, such as spontaneous thoughts (e.g., 'Have I left the stove on?', 'Should I drop this task and take a break?') (Thomson et al., 2015), affects, or interoceptive signals. Here, spontaneous thought is a double-edged sword: it can both decrease vigilance (Carter & van Veen, 2007) and elicit conflict detection, when the thought is registered as at odds with occurrent or planned behavior. Conflict detection, then, is needed for steering behavior in response to both external stimuli and spontaneous thought, allowing task shifting and the deployment of self-control to stay on task.

In brief, whenever new information is sampled, whether internally such as via memory retrieval or externally, there is a risk that some of that information is incongruent with a current task or with other information. This then results in conflict detection, even as sometimes conflicts also go undetected. Conflict detection can be adaptive, such as when the new information reveals an opportunity for a more valuable task (e.g. responding to a fire hazard). But it can also be maladaptive, as recurring conflict detection may make action indecisive and half-hearted and may make staying on task more difficult due to the resulting increased demands on downstream self-regulation.

### 4. Conflict monitoring as a general bottom-up self-control mechanism

In this section, I articulate implications of conflict monitoring for theorizing about self-control. As I will argue, appreciating the necessity of conflict detection for self-control carries implications for two central questions concerning self-control: the question to what extent self-

control is under top-down agential guidance, and the question to what extent there are mechanisms that generalize across self-control.

Above, the heterogeneity of self-control strategies was discussed, due to which unifying mechanisms for self-control are hard to identify: regulating one's behavior in motivational conflicts requires very different neural mechanisms if it is done via top-down attention reorienting or via situational strategies as opposed to inhibitory control. Often, the strategies deployed by agents include a set of mechanisms deployed jointly. For example, top-down guidance of attention can co-occur with, e.g., inhibition, construal, or situational strategies. However, while looking at the flexible top-down strategies agents deploy for self-control is informative, what it leaves outside its scope are the upstream mechanisms that are required for agents to deploy *any* such strategy. To remedy this, self-control research should pay more attention to conflict detection.

I here suggest that conflict detection is necessary for self-control. Whether an agent deploys self-control is contingent on whether conflict detection occurs, simply because self-control by definition is a response to occurrent or anticipated conflict. If there is a unified upstream mechanism of conflict detection, that mechanism then becomes general to all self-control regardless of which downstream strategies of self-control are deployed. And there is a very good case that there in fact is such a unified mechanism, realized by the interplay of the anterior cingulate cortex (ACC) and the ventral attention system (Carter & van Veen, 2007; Langner & Eickhoff, 2013; Walsh et al., 2011).

According to an influential theory, conflict detection is a function realized by the ACC (Botvinick et al., 2001; Carter & van Veen, 2007). This would explain the ACC's role in top-down control, as control by definition is only required when more than one, conflicting, response is presented or anticipated.

The ACC also responds to spurious error feedback, indicating that it is implicated not just in de facto conflict but signals of occurrent and anticipated uncertainty and error more broadly (Brown, 2017; Vassena et al., 2020). Another theory suggests the ACC's role is the computation of the value of control (Shenhav et al., 2016). Here, notice this does not exclude conflict detection but rather necessitates it. To anticipate error is to anticipate that a behavioral output is suboptimal, i.e. an output is erroneous only by comparison to a better output. Uncertainty likewise involves conflict detection, either with regard to behavioral outputs when the uncertainty concerns which output is best, or epistemic uncertainty when conflicting interpretations of the state of the world are present. The ascription of nonzero value to control requires the detection of conflict between controlled and non-controlled outputs. Thus, these broader functions of the ACC do not reduce to conflict detection, but conflict detection is part of each.

So, while conflict detection may be only a partial description of the ACC's functional role, it is retained in revised models as one important aspect of ACC function. No brain area accomplishes its tasks in isolation, and the case of conflict detection, ACC's connectivity with the locus coeruleus-norepinephrine (LC-NE) system is noteworthy (Carter & van Veen, 2007; Grueschow et al., 2020). The LC-NE system receives inputs from the ACC, and in turn feeds into the ventral attention network, suggesting it may play a crucial role in mediating between conflict detection and bottom-up attentional shifting (Corbetta et al., 2008).

The ACC is implicated across the cognitive control and ventral attention networks (Ahrens et al., 2019; Brown, 2017; Dixon et al., 2017). In cognitive control, its primary function appears to be the detection of response conflict (van Veen et al., 2001). The ACC is also implicated in the default mode network, which is associated with internally-directed cognition such as memory retrieval and spontaneous thought (Christoff, 2012). LC-NE function is also associated with attention shifting across both internally directed cognition and externally directed perception (Corbetta et al., 2008). This supports the view that a single neurocognitive mechanism of conflict detection may generalize across both exogenous and endogenous signals.

Here, one may wonder whether conflict detection is necessarily

bottom-up. People sometimes are vigilant in a top-down way (such as when a thinking, 'hmm, what do I need to notice that I didn't yet?'). However, such processing still reflects bottom-up conflict detection in two ways. First, top-down guided thought reflects a prior detection of uncertainty or conflict, again understood to encompass not just occurrent conflicting stimuli but also detection of occurrent and anticipated uncertainty or error. Top-down search for conflicting inputs, primarily realized by the dorsal attention system, is therefore itself preceded by signaling of uncertainty or conflict. Further, during that search, *whether and which* novel items occur to the agent who is engaging in top-down vigilance is not subject to volition. So, top-down search necessarily involves bottom-up conflict detection, although it does not reduce to it.

However, conflict detection is sensitive to top-down guidance. While registering conflict is in itself a bottom-up, nonvolitional mechanism, whether a given cue elicits conflict detection is task-sensitive: for example, the same stimulus may register as conflicting under a given task condition, but not under another. Task parameters thus *contribute* to encoding whether stimuli are registered as incongruent (Botvinick et al., 2001), although they do not fully *determine* it. Such indirect guidance can be accomplished through self-control strategies, a point I discuss further in Section 6.

Conflict detection thus emerges as a crucial mechanism for self-control (Kotabe & Hofmann, 2015). It is, of course, not a *dedicated* mechanism: just as was the case with inhibition, discussed above, conflict detection enables agents to flexibly adjust their behavior in multiple ways, not all of which involve self-control. This is unsurprising because conflict detection is a very general function. However, unlike inhibition, which is not relevant for all self-control, conflict detection is *general* to self-control.

Even if not dedicated, identifying mechanisms that generalize across self-control is helpful. From a theoretical perspective, it helps build a bridge between functionalists about self-control and those who wish to identify self-control by reference to mechanisms general to it. This is because, while functionalists about self-control define it in multiple ways, what these definitions share is the conception that self-control is something that helps agents navigate motivational conflict, such as between a larger later and a smaller sooner reward, or between intentional action and impulsive behavior (Duckworth et al., 2016; Kennett, 2001; Koi, 2023; Levy, 2017; Mele, 1995). For this reason, functionalists including the present author must allow that conflict detection is necessary for the occurrence of self-control. And, if there is a unified mechanism for conflict detection, then that mechanism would likewise be necessary for the occurrence of self-control. This yields a novel argument for the mechanistic unification of self-control: even if the downstream mechanisms and strategies of self-control are many, they would nonetheless converge on a shared upstream neurocognitive mechanism.

As described above, while top-down guidance contributes to the parameters against which certain signals are detected as conflicting, occurrent conflict detection itself remains a bottom-up mechanism. On a typical self-control case, the agent is on task or has a prior commitment. Bottom-up conflict detection occurs, allowing the agent to register the incompatibility of responses, appraise whether control is required, and deploy control accordingly. But even as task-oriented guidance helps calibrate what signals are registered as conflicting, its influence is only partial. An agent on task may thus veer off task not just due to a failed attempt at control, but also because conflict was not registered. Here, while top-down processes map out the task space, conflict detection as a mechanism is bottom-up, and more directly connected to the ventral rather than dorsal attention network.

A conceptual issue that arises here is whether conflict detection is best analyzed as a mechanism of self-control, or as a mechanism that necessarily *precedes* self-control proper. That is, even if conflict detection is *necessary* for self-control, not all would accept that it is a mechanism of self-control in the sense of being something that is a component of self-control, rather than just its antecedent.

This is not merely a question of terminology. Instead, it reflects diverging views of the nature of self-control. If we analyze self-control from a behavioral perspective simply as the successful matching of behavior with intent despite motivational conflict, then conflict detection seems best understood as a mechanism of self-control. However, not all are happy with such an approach: in philosophy, perspectives that take self-control by definition to pertain to the guidance of top-down processes abound, where self-control by definition is e.g. active (Kalis, 2018), actional (Mele, 1995, 2009, p. 178), and/or involves mental effort (Irving et al., 2022; Sripada, 2021). If we take action to necessitate top-down guidance, and since conflict detection mechanism is not under such guidance, then *whether* we engage in self-control is determined non-actionally – even as guidance and corresponding actionality may subsequently arise during the self-control process.

The centrality of top-down guidance for self-control has been questioned, chiefly by authors who emphasise diachronic forms of self-control (Kennett & Smith, 1996; Koi, 2023, 2024; Levy, 2011; Vierkant, 2015). Of these, Kennett and Smith suggest self-control is best conceived as non-actional (Kennett & Smith, 1996, 1997). Appreciating the non-actional nature of conflict detection does not however require us to construe all of self-control as non-actional. Those who are committed to the view that self-control is top-down and actional by definition may find self-control's non-actional beginnings counterintuitive. While few would think self-control would be top-down in the sense of exclusively recruiting top-down processes with no bottom-up contributions, the beginning stages of self-control carry particular importance for the question whether self-control is actional. So, even on a construal of self-control as top-down in the lenient sense that it involves or entails top-down regulation, in which case top-down regulation need not permeate the self-control process throughout, one could arguably claim that if *whether* self-control is deployed is contingent on bottom-up conflict detection, our views concerning self-control's agentiality will be transformed. For one, “the view that self-control exertions are something we intentionally do, not merely something that happens to us” (Bermúdez, 2021) becomes only partially true, as we need to relax the assumption that exercising self-control is a choice. In a sense, conflict detection happens to us, even as we can indirectly modulate the likelihood that we detect specific types of conflict; I will discuss this at more length in Section 6. Nevertheless, when self-control is deployed, active doing is often implied: we actively and skilfully navigate different strategies to regulate our behavior (Bermúdez, 2021).

In brief, appreciating the role of conflict detection for self-control implies that 1) the deployment of self-control may be actional in the sense of sensitive to guidance, but initiating it is not under direct volitional control; and 2) self-control's potential actionality emerges during the self-control process.

Ultimately, those who are committed to the view that self-control is top-down by definition, need not discount the importance of conflict detection for self-control nor reject the main claims of this paper. They instead could frame the resulting architecture of self-control as two-part, where the nonvolitional 'roots' of self-control are conceptually distinct from self-control proper. But even thus, the point about self-control's nonvolitional origins persists.

## 5. Individual differences, conflict detection, and ADHD

From the perspective of inquiry into individual differences in self-control and their clinical implications, understanding self-control difficulties is greatly aided by identifying mechanisms of self-control – breakdowns of which would then emerge as sources for self-control difficulties and self-control failure. In prior research, multiple self-control strategies beyond inhibition have been identified (Duckworth et al., 2016). Inhibition does not seem to outperform other self-control strategies, casting doubt on whether inhibition deserves to be thought of as a paradigmatic self-control process (Bürgler et al., 2021; Duckworth et al., 2016; Hofmann, 2024). Koi argues that individual

differences in self-control are best explained by differences in whether agents have access to feasible self-control strategies, which could help explain, e.g., the vast variability in ADHD's effect on self-control (Koi, 2021, 2023). ADHD is often dubbed a disorder of self-control (Barkley, 1997), yet some people with ADHD successfully lead lives that put major requirements on their self-control. For Koi, this is explained by the presence of a robust toolkit of self-control strategies that are less heavily reliant on cognitive mechanisms implicated in ADHD, such as inhibition. By contrast, on Koi's account, people with ADHD who struggle with self-control may do so because they lack access to self-control strategies that are a good fit for their cognitive phenotype.

Appreciating conflict detection's necessity for the deployment of self-control helps us pinpoint a source of individual differences in self-control that is not directly contingent on strategy availability. Namely, it is plausible that differences in the dynamics of conflict detection are one of the sources of individual differences in self-control. This is, first, because differences in conflict detection may lead to failure to regulate behavior due to not detecting a conflict. But also, conversely, staying on task benefits from not detecting conflicts while on task. It is therefore paramount for self-control success that the dynamics of monitoring work in an adaptive way, detecting relevant conflicts while not exploring for irrelevant conflicting stimuli while on task.

Inattention and trouble staying on task are central traits associated with ADHD. There is increasing evidence that these are in fact connected: namely, in ADHD, differences in the activity of the default mode network cause hyperactivation of the ventral attention network. This entails that in people with ADHD, nonvoluntary, ventral exploration occurs more readily than in others, resulting in detection of task-incongruent stimuli even when exploitation rather than exploration would be adaptive (Addicott et al., 2017; Barack et al., 2024; Blomberg et al., 2022; Cortese et al., 2012; Liu et al., 2024; Sonuga-Barke & Castellanos, 2007). As suggested by Sonuga-Barke and Castellanos (Sonuga-Barke & Castellanos, 2007), lapses of task-oriented attention that are standardly thought to indicate impaired top-down control may often instead reflect bottom-up direction of attention to task-irrelevant stimuli.

What this entails for self-control is that in addition to forms of self-control that rely on top-down cognitive control, forms of self-control that require sustained attention are particularly vulnerable to disruption in people with ADHD (as well as with others with heightened propensity for spontaneous exploration), not due to supposed ‘weakness of will’ (Koi, 2024; Levy, 2011) nor, necessarily, impaired top-down regulatory processing, but due to heightened spontaneous exploration and conflict detection (Addicott et al., 2021; Barack et al., 2024).

## 6. Putting it all together: the dynamics of conflict detection in self-control

Self-control lapses, I have suggested, often occur due to nonadaptive conflict detection. They may occur because conflict is not registered: for example, an academic resolves to first write on their laptop and only then to surf the web on it, but when she opens the laptop, she finds herself online – not having registered the conflict before initiating the task-irrelevant behavior. Or, they may occur due to over-ready detection of conflict cues, resulting in *too much* conflict detection: for example, an academic resolves to write on their laptop, but her attention keeps wandering to a competing task – say, to do the dishes, surf the web, or respond to an e-mail – a conflict she must then resolve in favor of writing each time she detects it, which increases control demands and make her more vulnerable to an eventual lapse of control.

I have claimed that the occurrence of self-control is contingent on conflict detection, which is spontaneous rather than voluntary. Therefore, while self-control may involve top-down regulation, its ‘roots’ are in a bottom-up neurocognitive mechanism.

Rather than making self-control a matter of luck where agents have no choice but to hope for adaptive conflict detection, this places a

premium on agents' ability to indirectly modulate the availability of task-incongruent stimuli when seeking to control themselves to stay on task. Likewise, for lapses of self-control that are due to a lack of conflict detection, there is no principled reason why agents could not attempt to indirectly influence how likely they are to notice a relevant conflict. Thus, as Murray and colleagues point out, control requires information management (Murray & Vargas, 2020), and maintaining vigilance is a problem in which agents deploy a variety of metacognitive and other strategies (Murray & Amaya, 2024). In this article, I have suggested a mechanistic approach to describing this phenomenon: when we appreciate that conflict detection is necessary for self-control, strategies that indirectly modulate conflict detection become an important form of indirect agential guidance.

As mentioned before, a growing body of self-control research highlights the importance of a set of strategies through which agents indirectly and diachronically influence their future behavior (Bermúdez, 2021; Duckworth et al., 2016; Gillebaart & de Ridder, 2015; Kennett & Wolfendale, 2019; Koi, 2023; Snoek et al., 2016; Vierkant, 2015). While the primary target of these strategies is behavior regulation, many of these strategies putatively are helpful precisely because they, e.g., limit the availability of task-incongruent stimuli, thus decreasing the odds that such stimuli are registered. For example, when a student goes to study in the library rather than staying at home, many competing tasks – from doing the laundry to playing a game – become 'out of sight, out of mind'. Of course, these strategies do not fully preclude the sampling of these competing tasks, as they do not preclude internally generated cues. Further, agents are differently positioned in terms of whether they can access various strategies of self-regulation (Koi, 2023).

While it is intuitive that many self-control strategies influence subsequent behavior partially or entirely through facilitating adaptive conflict detection, for many self-control strategies, it is unclear whether they affect self-control via conflict detection, by supporting top-down control, or both. In future self-control research, it would be helpful to disambiguate between the effect of self-control strategies on mechanisms of conflict detection and top-down regulation.

What this gives rise to is a dual-loop architecture for the dynamics of conflict detection in self-control (see Fig. 1). In the externally driven loop, an external stimulus elicits conflict detection and appraisal of an occurring or anticipated conflict. If self-control is required, top-down self-control strategies are then engaged; these can be heavy on occurring top-down cognitive control or else reliant on alternative top-down strategies, such as situation selection. Through subsequent behavior, agents can adjust exposure to conflicting stimuli.

In the internally driven loop, an internal signal such as spontaneous thought (Christoff et al., 2016) or metacognitive feeling (Fernández Velasco & Loev, 2025) elicits conflict detection and appraisal, allowing for the deployment of self-regulation strategies. However, rather than adjusting situational exposure to stimuli, insofar as agents can influence subsequent spontaneous thought, this is likely best done via metacognition or cognitive change. Here, research on how the contents of subsequent spontaneous thought can be regulated is still emerging. For example, implementation intentions may facilitate goal recall (Achtziger et al., 2012). Fox and Christoff (2014) suggest that while metacognition synchronous with mind-wandering can stifle spontaneous thought, metacognitive appraisal can help steer subsequent spontaneous thought towards directions previously assessed as adaptive. Likewise, Phillips and colleagues (Phillips et al., 2019), in probing which possible actions occur to agents, highlight that evaluation shapes spontaneous thought: in spontaneous generation of action possibilities, the generated possibilities are ones that agents assess as valuable and probable. However, the above should be regarded as tentative, and further research is needed on how agents facilitate the generation of adaptive internally generated cues.

Crucially, the externally and internally driven loops converge at conflict detection, and they share the pathway from conflict detection to the appraisal stage, in which the system processes whether to deploy

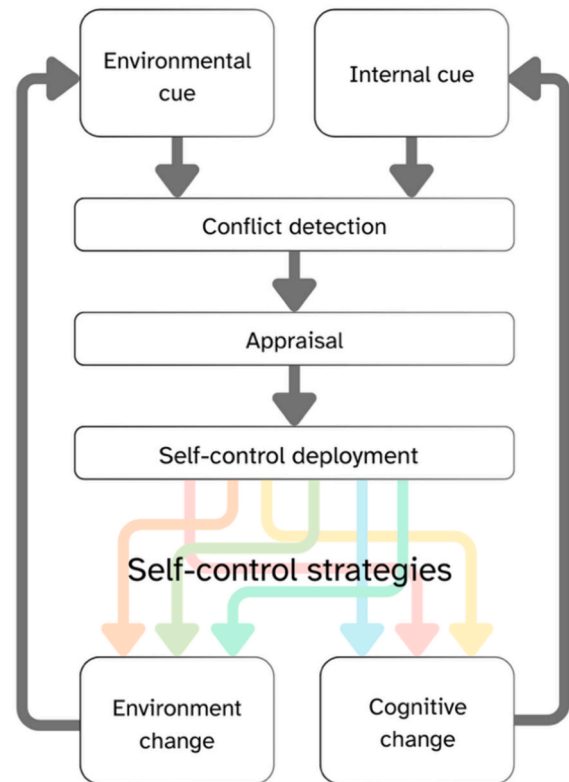


Fig. 1. A schematic model of the dynamics of conflict detection in self-control. Conflict detection is elicited by an environmental stimulus or an internal cue, such as spontaneous thought or metacognitive feeling. Conflict detection in turn elicits appraisal, where the agent determines whether self-control is required. If required, self-control is deployed by means of heterogeneous strategies that can both modulate behavior and indirectly shape future conflict detection—either via cognitive change, aimed at shaping future internal cues, or environmental change, which alters exposure to external stimuli.

self-control. If self-control is deployed, the relevant processes again become heterogeneous, as a range of processes can fulfil the role of steering subsequent behavior to align with perceived aims.

In this schematic model, conflict detection, appraisal, and control deployment are treated as modular, sequential steps for clarity. However, these processes are not isolated from each other, and they could also occur in parallel. The relationships indicated by the arrows could then not indicate sequence but instead dependence or mediation: for example, appraisal of the value of control is contingent on conflict detection, and environment change mediates the presence of environmental cues. Thus, when Mylopoulos & Pacherie, in discussing the nature of intention, suggest that “having two segregated detection and selection stages would not be very efficient from a computational point of view” (Mylopoulos & Pacherie, 2019, p. 6), I take their point to be that if these modules were isolate from each other, then both would need to carry out the complex computational task of prioritizing information. However, if computation of value in one stage of the process feeds forward into another, redundant processing across the same information is avoided. This can be accomplished both across a sequential model in which each stage provides input for the next, and in parallel processing where computation of value (appraisal) provides inputs into other parallel processes, such as control deployment.

## 7. Conclusions and future directions

Spontaneous attention plays multiple roles in self-control. It has long been recognized that some, though not all, self-control strategies revolve on the top-down guidance of attention, and on avoiding the task-

irrelevant recruitment of spontaneous attention. Spontaneous attention is often seen simply as a distraction, or something that is detrimental to self-control and goal-directed action more broadly. However, contrary to this simplistic picture, it is not true that spontaneous attention would be merely detrimental to self-control. Instead, since the deployment of self-control is contingent on conflict detection, without spontaneous attention, self-control could not occur.

A prominent debate within the self-control literature has been whether self-control is best understood in functionalist terms, or whether instead there is a process or mechanism that is general to self-control or even unifies it as a kind. Above, I have suggested that conflict detection is general (but not dedicated) to self-control. If my argument is sound, then functionalists about self-control, who endorse that self-control can be realized by multiple different strategies, must concede that conflict detection as realized by the ACC and the ventral attention pathway is a general mechanism of self-control. However, our knowledge of conflict detection is currently predominantly general, rather than domain-specific. While the ACC's role in cognitive control is specific to the detection of response conflict (van Veen et al., 2001), more research is needed on whether the neurocognitive mechanisms of conflict detection for control, e.g. for staying on task, diverges from mechanisms of conflict detection in other domains.

Self-control is typically seen as volitional: something we choose to deploy to stick by our commitments. However, since conflict detection is not under conscious choice, if volitionality entails such choice, then self-control begins nonvolitionally. While the account developed here supports views according to which self-control may be non-actional (Kennett & Smith, 1997), it does not require us to construe of self-control as devoid of agency. Instead, agential guidance may emerge during the self-control process even if it is not present in occurrent conflict detection. Also, the nonvolitional nature of occurrent conflict detection does not entail that agents could not influence their subsequent self-control. Instead, it suggests that agents can endeavor to indirectly promote adaptive conflict detection, and to indirectly decrease the likelihood of maladaptive conflict detection.

In philosophical literature, spontaneous thought is often linked to character (Chappell, 2001). Future research could address to what extent the development of habit (Hornett, 2023; Kalis & Ometto, 2021; Proust, 2015) or of virtue and character (Sinnott-Armstrong & Miller, 2017) could result in dispositions for adaptive rather than maladaptive conflict detection. Tentative support for this notion is found in the modulating effect of reinforcement learning on conflict detection (Holroyd & Yeung, 2012).

Most importantly, appreciating that non-self-controlled behaviors may stem from maladaptive conflict detection rather than from impaired top-down regulation highlights limitations for top-down models of self-control. Namely, impairments of top-down control cannot then be inferred from behavior, as maladaptive conflict detection may also yield non-self-controlled behavior in the absence of impaired top-down regulation. Due to this, self-control theories focusing on top-down control also may yield misguided intervention predictions, as they emphasise supporting top-down regulatory capacity, but such support should yield limited results when the core cause is maladaptive conflict detection. Rather than supporting top-down control alone, self-control interventions should also address conflict detection. Distinguishing between these sources of self-control struggles could be of clinical significance, as it would help assess which forms of intervention should be prioritized.

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## Data availability

No data was used for the research described in the article.

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