CHAPTER TWO

Between Persistence and Flexibility: The Yin and Yang of Action Control

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Abstract

Traditional approaches to action control assume the existence of a more or less unitary control system that struggles with, and serves to overcome action tendencies induced by automatic processes. In this article, I point out that and why these approaches fail to capture the complexity and dynamics of cognitive control. I describe an alternative approach that assumes that control emerges from the interaction of at least two counteracting forces: one system promoting persistence and the maintenance of action goals and another promoting mental and behavioral flexibility. I describe how this interaction might be shaped by various factors, including genetic predisposition, learning, personal experience, and the cultural context, and suggest a simple functional model (the Metacontrol State Model, MSM) that explains how this shaping process works. Then I provide an overview of studies from various fields (including perception, attention, performance monitoring, conflict resolution, creativity, meditation, religion, and interpersonal perception and behavior) that successfully tested predictions from the MSM.

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1. INTRODUCTION

Human action is often goal-oriented (to a degree that the existence of goals is often considered to be the defining aspect of human action), often initiated in the absence of action-related external stimulation, often spontaneous and nonhabitual, and can commonly be adjusted rapidly if no longer functional or not meeting situational challenges. The human capacity to achieve all of this is commonly ascribed to what we now call cognitive control or executive functions. The general idea is that the processes captured by these labels constitute a kind of second layer of information processing: while the first layer consists of basic processes to translate stimulation or input (the terms preferred by behavioristic and information-processing approaches, respectively)—such as sensory registration, identification, attentional selection, response decision, and motor execution—the second layer operates on the first by rewiring the respective processes in such a way that behavior is optimized and intended goals are reached (e.g., Verbruggen, McLaren, & Chambers, 2014).

Even though the terms cognitive control and executive function are relatively new (with Atkinson & Shiffrin, 1968; as one of the first proponents), the underlying concepts and the investigation of the underlying mechanisms are much older. In the following, I will discuss two predecessors and the related theoretical implications that have survived the terminological transition and that still dominate the discussion of human action control. Concepts that are used for such a long time and that have stimulated so much research are unlikely to be entirely incorrect, but I do think that they have limitations that need to be overcome in future research. I will thus present an alternative view of human action control, at least of some relevant aspects of it, that is also not without predecessors but has the advantage of providing a more dynamic, and thus probably more realistic, view of how humans keep their actions adaptive. I will begin by discussing two more traditional and popular views of action control—one assuming a *will* that is fighting against habits and another assuming an *ego* that mediates between societal requirements and personal urges—and point out a number of limitations of these views. Then I will synthesize the positive aspects of these two views and bring them together with more recent ideas from cognitive psychology and the cognitive neurosciences, to construct a more dynamic approach to human action control. Finally, I will sketch major determinants of the operation characteristics of control functions and provide some empirical examples to illustrate and justify my choices. However, I will not start without emphasizing that this chapter is a (empirical and theoretical) work in progress, a developing theoretical approach rather than a complete theory.

2. THE WILL

Approaches to human action control are older than the first psychological laboratory, which explains why they were commonly focusing on the conscious experience of control—the major empirical tool of nonexperimental researchers. The dominant view during the years in which the first laboratories were established was ideomotor theory, which has an even longer philosophical tradition (Stock & Stock, 2004). The approach focuses on the process of gaining control over one's body and its movements. It basically assumes that perceptual impressions of actively achieved changes in one's environment are automatically associated with whatever motor pattern was used to achieve them (for a review, see Hommel, 2009). Once these associations are created, the agent can reactivate the codes underlying the perceptual impressions at will and thereby automatically prime the associated motor patterns—the motor system thus becomes a slave of the will, as it were.

As the first experimental investigations of human cognition were focusing on perception, ideomotor theory and the will in general did not receive substantial empirical attention until the early 1900s. Around that time, experimental methods were developed to assess the time it takes to implement a particular action goal (e.g., Michotte & Prüm, 1911) and the impact of implementing a particular goal on information processing and conscious experience (Ach, 1910, 1935). Of particular interest, even the very first attempts to assess human will were using a scenario that survives to this day: Ach (1910) argued that the best and most objective way to measure the human will requires putting it in opposition to a counteracting force, which according to Ach was habit. Following this rationale, he developed methods to strengthen particular stimulus–response associations through repetition (e.g., by having participants produce rhyming responses to sequences of nonsense syllables) and then tested the degree of willpower by requiring the participant to produce a different response on old versus new items (for an overview, see Hommel, 2000a). As expected, items that were previously associated with a different action category were more difficult and took more time to respond to than new or familiar, but previously unassociated items. In numerous studies, Ach and colleagues demonstrated that the size of this interference effect varies systematically with the strength of the previously induced habit and/or the strength of the exerted or individually available willpower (for an overview, see Ach, 1935).

Note the similarity between this approach and the now popular rationale to assess the existence and efficiency of cognitive control functions by analyzing how much they are hampered by stimuli that are (or have been) associated with goal-incongruent responses—such as in Stroop, Simon, or flanker tasks (e.g., Hommel, 2000b). In fact, it is not only the experimental approach that is still heavily used, but the theoretical framework has remained in place as well. It comes in several flavors. The revival at the end of the 1960s along the lines of Atkinson and Shiffrin (1968) was basically replacing the apparently outdated terms "will" and "habit" by the more depersonalized terms "cognitive control" (or executive control, or executive function) and "automatic processes." As in the original framework, novel and unfamiliar actions were supposed to rely on control processes to configure the cognitive system while overlearned actions could rely on automatic processes and thus require little or no control. The basic idea was that learning is the mechanism that creates automaticity over time by building more or less direct associations between stimulus representations and response representations (e.g., Kornblum, Hasbroucq, & Osman, 1990; de Wit & Dickinson, 2009). There is a long-standing controversy with regard to the question how automatic processes or automaticity need to be characterized, and it is fair to say that no universal criterion has been found so far. Some authors have advocated nonintentionality as the key criterion while others have suggested the ballistic, nonsuppressible nature of automatic processes, and even others have favored the lack of (commonly not further defined) "cognitive" or "central" resources needed to run automatic processes or the immunity to interference from other processes (e.g., Bargh, 1994; Moors & De Houwer, 2006).

The major problem underlying discussions and theoretical considerations of that sort is that they are facing a classical Rylean category issue (Ryle, 1949). This problem is a bit more transparent when one refers to the original concept of the "will." Will is something that persons have but not a characteristic of a nervous system—much like there is nothing in a particular building that reflects its being part of a university, as in Ryle's famous example. Obviously, the willing person has a nervous system and (if we accept the functionalist stance underlying the rationale of cognitive psychology and the cognitive neurosciences) the process of willing must be reflected in the activities of that system. Accordingly, it certainly makes sense to try to capture the functional and/or neural reflection of the process of willing, but it makes little sense to characterize particular processes as carrying or not carrying the essence of will. In fact, the exact same process may very well subserve "will" in one situation and conflict with it in another. Translating the personalized concept of will into the depersonalized concept of control may sound more objective and scientific (Goschke, 2003) but it does not address the basic logical problem.

Consider, for instance, automaticity in the Stroop task (Stroop, 1935). In this task, participants are to name the color of color words, and they are known to be slower to do that if the to-be-named color is inconsistent with the meaning of the word. The standard explanation from control/automaticity approaches is that this is because people are used to reading words rather than naming their color, which has automatized the reading process that now interferes with the intentional color-naming response (for a review, see MacLeod, 1991). Note that, in this example, the reading process is not uncontrolled: it is actually triggered, and thus under the control of the word and its meaning. In that sense, the reading process is not automatic. One might object that it is inconsistent with the action goal, and should in that sense be considered automatic. But that does not hold as well. It is known that the Stroop effect is very small (less than 10% of its original size) or absent in task versions operating with keypresses rather than overt naming responses (McClain, 1983) and that the few demonstrations of reliable effects are likely to result from internal naming (Chmiel, 1984; Martin, 1978). This implies that the reading response is actually contingent on, and therefore controlled by the goal to utter color words, which undermines the assumption that the reading response is automatic. How about functionality, one might object: could not one say that it is not useful to activate the reading response related to the word meaning, and that the fact that we nevertheless find evidence for such activation demonstrates automaticity? Even that approach is not tenable, as studies on the so-called Gratton effect (Gratton, Coles, & Donchin, 1992) have revealed. What these studies show is that the interference related to the nominally irrelevant word meaning is drastically reduced (if not eliminated) after incompatible trials, that is, after trials in which the word meaning suggested the wrong response. In contrast, interference increases after compatible trials, that is, after trials in which the word meaning suggested the correct response (e.g., Egner, 2007). But this means that the tendency to react to the nominally irrelevant stimulus feature is closely depending on its informational value and, hence, on its functionality for action control. And as this functionality depends on the action goal, which again is reflected in control processes, we must conclude that what seems like the automatic activation of word meaning is actually the goal-contingent, adaptive use of stimulus information that has just (i.e., in the previous trial) proven to support action control.

These considerations suggest that it makes little sense to contrast control and automatic processes and consider them to compete for action control, as the particularly popular dual-process models in the field are doing (for an overview and a defense of the control/automaticity dichotomy, see Verbruggen et al., 2014). Moreover, there is increasing evidence that what is considered to be control processes actually shows many characteristics of what is considered to be automatic. For instance, one of the key paradigms to investigate operations of cognitive control is using task switching (for a review, see Kiesel et al., 2010). Participants are asked to respond to particular stimuli according to one set of rules in some trials and according to another set of rules in other trials. The standard finding is that performance is better if the set of rules (i.e., the task) remains the same than if the task changes, which is commonly taken to reflect the extra demands required to implement a different task set—a control process. Interestingly, however, there is ample evidence that the implementation of tasks sets can be triggered by external stimuli (e.g., Waszak, Hommel, & Allport, 2003), even if these stimuli are masked to render them unconscious (Reuss, Kiesel, Kunde, & Hommel, 2011). Hence, there are good reasons to assume that in a particular trial, "control/led" and "automatic" processes are both under stimulus control (i.e., automatic) and contingent on the current action goal (i.e., controlled by "the agent"). This is consistent with approaches suggesting that planned action consists in self-automatization. As suggested by Exner (1879), Bargh (1989) and others, planning and preparing for an action comprises the implementation of all sorts of goal-contingent stimulus–response links that delegate the triggering and eventual execution of the action to the environment as far as possible—a kind of prepared reflex (Hommel, 2000b).

To summarize, there is considerable evidence that automatic processes are under surprisingly tight cognitive control while cognitive control processes can be triggered automatically and even in the absence of conscious awareness. In principle, this makes it impossible to identify clear-cut criteria to categorize processes according to that dichotomy, which undermines its usefulness. The popularity of the dichotomy is likely to emerge from its intuitive plausibility. Take, for instance, the example of substance addiction.

Many will know from their own experience that breaking with one's habits can be extremely difficult, such as quitting to smoke. Subjectively, the conflict emerges between the urge to smoke, especially in the presence of smoke-compatible stimuli or situations, and the insight that leading a healthy life requires one to quit. It is easy to see that this experience can be nicely couched in terms of a struggle between will (the intention to quit) and habit (the overlearned urge to smoke). However, it is a far cry from this everyday example expressed in everyday language to a theoretical contrast between what dual-pathway theorists would consider the control process (suggesting to quit) and the automatic process (suggesting to smoke). After all, the smoking response meets all sorts of criteria of what in other circumstances would count as a control process: it is expected to result and actually results in pleasure, fits with previous experience, has shown to be functional in many earlier situations, fits with preferred personal stereotypes (like admired actors that also smoked), and so forth and so on. Hence, there are many reasons to smoke and it seems far-fetched to reduce the tendency to consider them a mere reflex—in fact, even for those who want to quit, smoking is a goal-directed, intentional action. It is just that the intention is inconsistent with other intentions—a classical goal conflict.

Taken altogether, a closer look reveals that the intuitive opposition of control and automaticity makes little sense and fails to provide much help in characterizing and categorizing the processes underlying human action control. The main difference between what is commonly considered control processes and what is commonly considered automatic processes lies in the familiarity with the stimulus–response relationship and the recency of acquisition of the stimulus driving the action: while the stimuli driving the apparently more "automatic" processes have commonly been acquired much earlier, the stimuli driving "control" processes (i.e., the "if" parts of the instructed "if-then" rules) have been acquired or instructed more recently. While this difference may allow for a relative categorization of one process or stimulus–response association as more "automatic" than the other, it remains unclear what benefits such a relative categorization brings theoretically.

3. THE EGO

Another approach to human action control is Freudian in nature. According to Freud's (1923) personality model, human action control is haunted by the continuous conflict between societal rules and expectations (the Superego) on the one hand and of personal needs and urges (the Id) on the other. To deal with this conflict, humans develop an ego that mediates between the two conflicting parties and tries to identify suitable compromises and solutions. In many cases, acceptable solutions will consist in the inhibition of personal needs and urges, which means that inhibition processes play a dominant role in this approach.

More modern versions of the ego model, such as the attentional approach of Kahneman (1973) and the ego-depletion model of Baumeister, Bratslavsky, Muraven, and Tice (1998), have focused on the assumed capacity requirements of cognitive control. The basic assumption is that control operations require cognitive resources that automatic operations do not. This allows for a number of empirical predictions that have been tested with some success. For instance, extensive and repeated reliance on control operations should tend to exhaust the hypothetical resource, which should impair subsequent control operations, but not automatic operations, until the resource is refilled. Along the same lines, allowing the resource to refill, or supporting and speeding up the refill process, should eliminate the reduced efficiency of control operations.

The most problematic aspect of all available versions of ego or capacity theories is the notorious under-definition of the most central concept—the resource. In the context of attention theory, this has clearly stood in the way of a broader impact of the approach (Navon, 1984), even though it is still used, often in a rather metaphorical way in applied fields (e.g., Wickens, 1984). The main problem is that the failure to characterize the resource invites circular reasoning (if some process unexpectedly fails to suffer from resource depletion it can be easily declared automatic), which strictly speaking renders the approaches untestable (Navon, 1984). A related problem refers to the nature of the capacity limitation. Straightforward predictions only hold to the degree that the individual capacity limitation is fixed, so that the refill will always reestablish the original or optimal level. However, some approaches have considered the possibility that the individual capacity might vary (Kahneman, 1973). This is motivationally not implausible and would be consistent with the "difficulty law of motivation" proposed by Hillgruber (1912; see Hommel, Fischer, Colzato, van den Wildenberg, & Cellini, 2012). According to this law, the difficulty of an action is the motive for investing more effort and devoting more cognitive control to reach the task goal. If so, increasing task difficulty should automatically ("drive-like," as Hillgruber says) increase cognitive control without conscious deliberation, an idea that has lived on in several disguises (e.g., Kahneman, 1973; Kukla, 1972; for a review, see Brehm & Self, 1989) and been confirmed empirically (e.g., Hommel et al., 2012). In a certain sense, the law can be considered a predecessor of the control approach of Botvinick, Braver, Barch, Carter, and Cohen (2001), who suggested that registering processing problems lead to a stronger focus on task-relevant information—a classical control operation. However, while the assumption that individual capacity limitations can vary is theoretically reasonable and empirically plausible, it basically renders ego-depletion and other capacity models untestable.

Another Freudian approach, or family of approaches, focuses more on inhibition. According to Freudian theorizing, socially inappropriate behavior would be prevented by having the ego suppress corresponding drive-induced tendencies. Along the same lines, numerous approaches have argued that, given the evidence that many stimuli can trigger unwanted behavioral tendencies in conflict tasks (such as the reading response in the Stroop task), there must be an inhibitory system suppressing these tendencies (e.g., Ridderinkhof, Forstmann, Wylie, Burle, & van den Wildenberg, 2010). In fact, many dual-pathway models of action control have suggested the existence of such an inhibitory system, and individual differences in the efficiency of the assumed inhibitory system have been taken to account for various behavioral problems including addiction (for overviews, see Wiers & Stacy, 2006). Behavioral studies investigating the efficiency of inhibition processes have often used conflict tasks—following the rationale introduced by Ach (1910), with the assumption that more evidence of conflict-induced interference from "automatic" processes indicates less efficiency—and tasks assessing how fast people can abort an already planned or ongoing action (e.g., Ridderinkhof et al., 2010).

Unfortunately, inhibitory approaches suffer from no less than three theoretical problems that are commonly overlooked. First, assuming an inhibitory system that is independent from the system representing the action goal doubles the "loans of intelligence" that theory building should seek to minimize. As described by McCauley (1987), explaining the intelligence of behavior by the intelligence of some assumed subsystem does not provide but merely postpones an explanation. But "intelligence loans ought to be repaid!" as McCauley rightly emphasizes. To clarify, consider again our Stroop example. To account for the observation that participants report the correct color name most of the time, even though they are more used to reading the word, requires the assumption that the actual task or goal is represented somewhere in the system and that it regulates information processing in such a way that the perceived color is somehow translated into the appropriate color-naming response. This representation need not be explicit but it must somehow incorporate the relevant stimulus–response rules and impact information processing so as to apply them. Let us now change perspective and consider the hypothetical inhibitory system. It may be easy to imagine that such a system can register the presence of multiple conflicting response tendencies, but how can it know which one to inhibit? To know that it would need to have access to a representation of the stimulus–response rules, the ability to apply them to identify the correct response, and then use that knowledge to inhibit all other response tendencies. In other words, the inhibitory system needs to be as intelligent and knowledgeable as the goal system, which doubles the hypothesized intelligence. But if nature has equipped us with one system that already knows what the right response should be—the goal system as I call it—why would it provide us with an exact copy of it for inhibition purposes? Why would it not leave the work to the first system, which already has all the necessary information? Hence, assuming a separate inhibitory system strongly violates Occam's razor principle.

Second, almost all approaches to human decision-making share two basic assumptions (for a review, see Bogacz, 2007): that decision-making is competitive (i.e., multiple representations of alternatives actively compete for selection) and that it is selective and/or capacity-limited (so that often one or few of the competing alternatives can be selected at one time). Biologically plausible models commonly reflect these basic principles by assuming that increasing the evidence for one alternative directly reduces the probability for the other alternatives to be selected. In winner-take-all models, this is commonly translated into mutually inhibitory relationships between representations of alternatives. Accordingly, increasing the activation of the representation of one alternative would lead to the reduction of the activation of alternative representations up to a point where the activation of one representation is at maximum and the activations of all other representations is at some minimum or at least sufficiently low. Note that this can be described as an inhibitory process: every gain for the eventual winner implies a relative suppression of all losers. And yet, systems of that sort do not require any independent inhibitor—inhibition is the necessary consequence of combining competition with capacity limitations, as in every neural system. If so, the assumption of an independent inhibitory system is entirely redundant and, thus, unnecessary.

Third, inhibitory approaches commonly jump from the observation of conflict-induced processing costs to assumptions about the efficiency of inhibition. The idea is that, once activated, incorrect response tendencies need to be suppressed, which takes time. As it is the inhibitory system that is responsible for the suppression, the more time it takes, the less efficient the inhibitory system must be. However, following the considerations just discussed, another, more parsimonious interpretation is possible, if not more likely. If we combine the assumption of competitive selection and capacity limitations, the time it takes to activate a correct response against competing alternatives should depend on two factors: the degree to which the action goal (or the representations embodying it) "supports" (provides top-down support) for the representation of the correct response and the degree to which competing responses were activated. Both of these factors are relatively well understood. Neuroimaging studies have provided evidence that the degree of top-down support can fluctuate from trial to trial but that it is strengthened whenever selection becomes more difficult (Egner & Hirsch, 2005). The registration of such difficulty has been shown to increase the focus on task-relevant representations in working memory (van Veen & Carter, 2002), which again results in increased facilitation of goal-consistent representations—but not in increased inhibition of irrelevant information (Egner & Hirsch, 2005). This suggests that the consideration of decision-making as competitive and capacity limited is sufficient to account for strategic adjustments in action control, but leaves no space or need for a dedicated inhibitory system.

Along the same lines, a recent genetic study of Miyake, Friedman, and colleagues has provided evidence that inhibition is an emergent property of cognitive processing rather than a separable factor. In earlier approaches, Miyake et al. (2000) have suggested the existence of three major systems underlying cognitive control: one responsible for information update, another for shifting between tasks, and a third for inhibition. While the first two systems were also indicated in the later genetic study (Friedman et al., 2008), the third, inhibitory system was found to be more of a general characteristic of action control rather than a separable factor equivalent to updating and shifting. This fits with the idea that inhibition is a necessary by-product of competitive, capacity-limited selection.

4. CONTROL AS BALANCE

An obvious commonality of many of the control approaches discussed so far is that they assume one unitary system to take care of control. More recently, a number of authors have argued for a more complex approach that considers multiple components or subsystems of control. One influential example is the just-mentioned approach of Friedman, Miyake, and colleagues. From a more functional point of view, Goschke and colleagues (Goschke, 2003; Dreisbach & Goschke, 2004) have pointed out that cognitive control often faces control dilemmas that are binary in nature, with the choice between maintenance (or persistence) and flexibility being a crucial one. While a strong maintenance of goals helps concentrating on relevant information and suppressing irrelevant information, it increases the probability that this renders a cognitive system too inflexible and insensitive to alternative possibilities and reasons to give up ineffective action plans. In turn, focusing on flexibility facilitates switching between alternative possibilities and actions but increases the possibility of distraction and dysfunctional cross talk between cognitive representations. The challenge for cognitive control or metacontrol (i.e., the control of cognitive control) would thus be to find the right balance between persistence and flexibility for a given task and situation. Indeed, Goschke and colleagues have shown how instructions and task conditions can systematically bias control characteristics toward persistence or flexibility, and that doing so creates the expected trade-offs. For instance, Dreisbach and Goschke (2004) found that the induction of positive affect increases flexibility at the cost of persistence and Müller et al. (2008) showed that prospective monetary gains have comparable effects. Given the link between positive affect, reward expectations, and dopamine (Cools, 2008), Goschke and colleagues argue that dopamine plays a crucial role in defining the control policy of executive functions and shifting control between the poles of persistence and flexibility in particular.

This possible link between dopamine and control policies was also strongly emphasized by Cools and D'Esposito (Cools, 2008, 2012; Cools & D'Esposito, 2010). According to their approach, it is important to distinguish between at least two dopaminergic pathways—a mesofrontal pathway targeting the prefrontal cortex and a nigrostriatal pathway targeting the striatum. Prefrontal cortex and striatum are assumed to play opposite roles in determining control policies, with the prefrontal component propagating persistence and the striatal component supporting flexibility. This is consistent with numerous findings suggesting a dominant role of the prefrontal cortex in behavior and cognitive skills requiring the maintenance of information, such as working memory, and a dominant role of the striatum in behavior and cognitive skills that require cognitive flexibility, such as in tasks calling for a frequent update of information. A particularly important implication of the approach relates to individual differences. As indicated by many pharmacological studies, neurotransmitters like dopamine do not have linear performance characteristics (i.e., more is not necessarily better), but follow an inverted U-shaped function, with best performance or efficiency related to medium levels (Cools & D'Esposito, 2011). This means that interventions that are affecting the current dopamine level are likely to have different implications for individuals with low versus high baseline levels, and there is indeed evidence that many dopamine-targeting interventions tend to "overdose" people with high dopamine levels. For instance, while positive mood is commonly assumed to improve creativity (for a review, see Baas, De Dreu, & Nijstad, 2008), this effect seems to be limited to individuals with low striatal dopamine levels (Akbari Chermahini & Hommel, 2012a).

With a stronger emphasis on dopaminergic receptor families, Durstewitz and Seamans (2008) have proposed a dual-state framework. These authors focus on prefrontal cortex and point out that the dopamine targeting this area is mainly processed by receptors from two families: D1- and D2-class receptors. They discuss empirical and modeling evidence that the prefrontal cortex can assume two different control states: One is characterized by the dominance of D1 receptors, which is accompanied by high performance in tasks requiring the maintenance of information. The other is characterized by the dominance of D2 receptors, which is accompanied by high performance in tasks requiring flexibility in the switching between options. The idea is that control policies are realized by shifting between D1- and D2-dominated states of the prefrontal cortex, which amounts to finding the right balance between persistence and flexibility.

Taken altogether, these available approaches differ in emphasis and level of analysis, but they provide a nicely converging picture. All approaches emphasize the existence of more than one executive control function, which goes beyond will- or ego-based unifactorial models. This does not necessarily render these more simple models incorrect, it just suggests that they underestimate the complexity and dynamical properties of cognitive control. Moreover, apart from the more conceptually oriented psychometric approach of Friedman, Miyake, and colleagues, all approaches emphasize the interactive, to a considerable degree even oppositional nature of the interactions between the components of cognitive control. This suggests that control emerges from the competition between at least two systems, one propagating persistence and the other propagating flexibility. The particular balance or imbalance between these two systems determines the (meta)control policy, that is, the performance characteristic of the control system. The more neuroscientifically interested approaches consider dopamine the crucial mediator that, in interaction with existing dopamine levels, control the relative impact of the two counteracting systems. One of these systems seems to be, or at least includes the prefrontal cortex, which is targeted by the mesofrontal dopaminergic pathway. The other system seems to be, or includes, the striatum targeted by the nigrostriatal dopaminergic pathway. Interestingly, dopaminergic receptors are not equally distributed over these two systems: While the prefrontal cortex is dominated by D1-family receptors, the striatum is dominated by D2 receptors (Beaulieu & Gainetdinov, 2011). This renders the approaches of Cools and D'Esposito (2010) and of Durstewitz and Seamans (2008) highly compatible, arguably even functionally equivalent, as D1 dominance would directly translate into a stronger relative contribution of the prefrontal cortex and D2 dominance into a stronger relative contribution of the striatum.

5. THE METACONTROL STATE MODEL

In the following, I will provide a brief overview of work led by Lorenza Colzato and myself that was guided by the idea that cognitive control may not be a unitary function but emerges from the interaction of two counteracting forces (or metacontrol states), which renders our approach a part of a broader family of control accounts that also includes the discussed approaches of Goschke and colleagues, Cools and D'Esposito, and Durstewitz and Seamans. Hence, even though most of our studies were targeting a coarser level of analysis and were thus less committed to particular brain areas and receptor families, we consider our general approach consistent and compatible with these other approaches and we were greatly inspired by them.

Given that we were interested in bringing together phenomena related to cognitive control from various levels of complexity, it was necessary to generalize and simplify the idea of (meta)control as balance, and to make it more concrete at the same time. To achieve that, we tried to relate this idea to existing models of human decision-making and considered how changes in balance—that is, changes in control style from more persistence to more flexibility, and vice versa—might affect decision-making processes. According to Bogacz (2007), there is a general modeling trend from earlier evidence collection models, which assume that representations of to-be-decided-upon alternatives collect internal and external stimulus information speaking in their favor, to more competitive models that reach decisions more quickly and that have greater biological plausibility. Figure 1(a) shows the minimal requirements for a competitive model: For one, the two or more alternative representations are competitive, which means that increases in activation of one reduce the activation of the other (until one of them reaches a certain threshold)—which in the figure is indicated by the mutually inhibitory links between the alternatives. Note that the resulting competition amounts to a capacity limitation along the lines discussed above, and that it leads to inhibition of less supported alternatives without the need of having a separate inhibiting system. As alternatives may receive some support from congruent internal or external sources, the dynamics of the interaction will have properties that random walk and diffusion models (e.g., Ratcliff & Rouder, 1998) are trying to capture. The second ingredient that biologically plausible competitive models need is some specific support from sources reflecting the current goal, which corresponds to what is considered top-down support in many modeling approaches (e.g., Desimone & Duncan, 1995). It is this input that makes sure that the "walk" is eventually not "random" but that the eventual decision is consistent with the current goal, at least in most of the cases.

How might a bias toward more persistence or more flexibility be integrated in such a minimal model? According to Hommel and Colzato (2010) and Hommel (2012) there are at least two, not necessarily mutually exclusive possibilities. One consists in increasing impact of the goal to increase persistence (as indicated in Figure 1(b)) and reduce it to achieve flexibility (Figure 1(d)). An increase will make it more likely that the most goal-consistent alternative will eventually be selected and it will make it easier to suppress less consistent or irrelevant alternatives, which would make decision-making more efficient, more selective, and more focused. In contrast, a reduced impact of the goal will increase the possibility that goal-inconsistent alternatives will be selected and lead to a stronger impact of irrelevant alternatives, but it facilitates the switch to other alternatives and the consideration of multiple alternatives in quick succession. The other possibility would be to strengthen (Figure 1(c)) or weaken (Figure 1(e)) the competitiveness between alternatives to achieve persistence and flexibility, respectively. The consequences would be more or less the same as for the modulation of goal impact, only that the modulation of competitiveness might introduce more goal-unrelated influences on the activation of alternatives. As these two possibilities have turned out to be difficult to disentangle empirically so far, and as they may very well be concurrently applied, I will not try to discriminate between them in what follows. Instead, I will assume, for the sake of simplicity, that changes of control styles affect both the impact of the goal and the competitiveness between

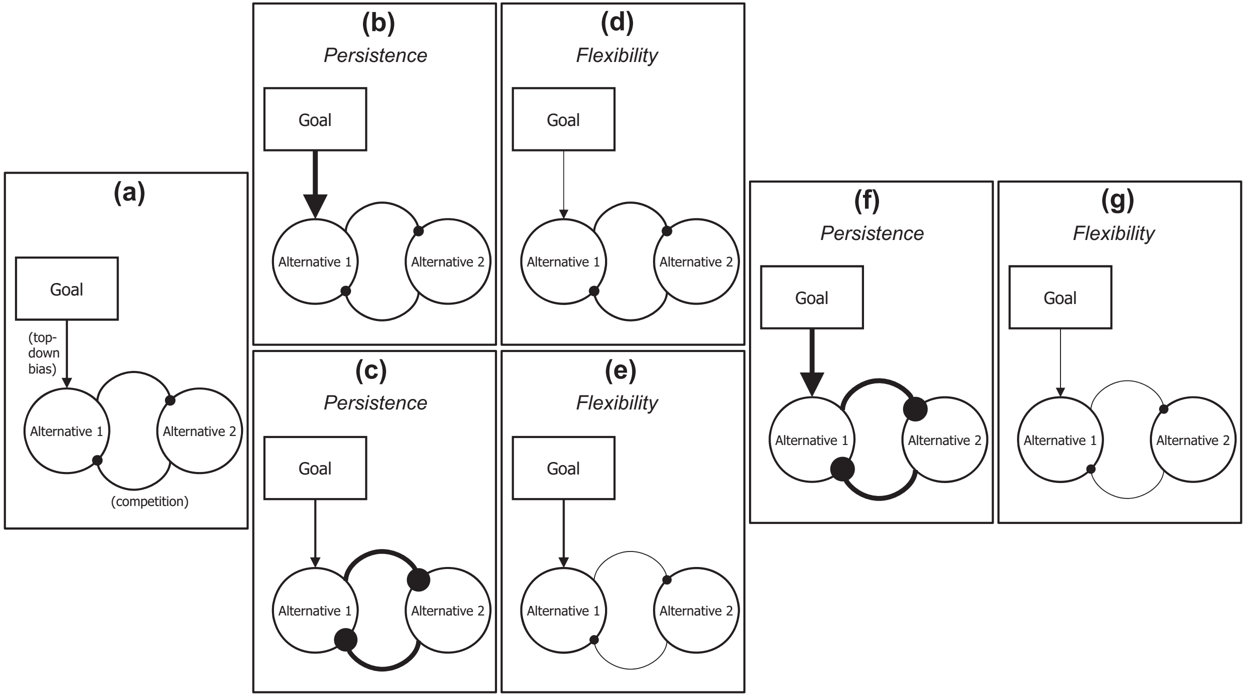

Figure 1 Possible mechanisms involved in competitive decision-making. The goal-related Alternative 1 is supported by the goal representation (which provides a "top-down bias"), but competes with choice Alternative 2 for selection through mutual inhibition ("competition"). Selection requires one alternative to pass a certain threshold (not shown), which given the mutual inhibition would result in the relative inhibition of the nonselected alternative. (a) shows the generic model; (b) and (d) show how strong persistence and pronounced flexibility might be achieved by modulating the strength of the top-down support from goal representations, respectively; (c) and (e) show how strong persistence and pronounced flexibility might be achieved by modulating the strength of mutual inhibition between alternatives, respectively; and (f) and (g) show the assumptions underlying the discussion in this chapter, which combine both possible mechanisms (goal modulation and the modulation of mutual inhibition).

alternatives, as indicated in Figure 1(f) and (g). In the following, I will use this model, which I will refer to as the *Metacontrol State Model* (or MSM), to explain how situational circumstances, experience, learning, and people's cultural context can bias cognitive control states, and the information-processing characteristics they control, in predictable ways and even create chronic biases that outlive the conditions for which they were originally created.

6. THE PLASTICITY OF CONTROL STATES

Task-switching studies have revealed that establishing a control state to orchestrate a new task takes quite some time, often in the neighborhood of half a second or a second (for a review, see Kiesel et al., 2010). Even though the duration of establishing a new control state has been considered to depend on the number of to-be-changed control parameters (Logan & Gordon, 2001) and the degree to which the new task set had been inhibited in earlier trials (Mayr & Keele, 2000), most approaches implicitly or explicitly assume that the remains of previous control states are fully eliminated before the new task will be executed. However, there are some indications that this scenario is not realistic. For one, the first systematic studies on task switching have already shown that previous control states can be sticky and affect later control even after a new state has been implemented (Allport, Styles, & Hsieh, 1994). For another, there are some indications in the literature that parameters of previously established states can systematically bias the characteristics of later states (Förster, 2012). These priming-like effects are particularly interesting from a MSM point of view, as I will elaborate in the next section.

While short-term transfer of control-state characteristics from one task to another supports the assumption that control states are inert, inertia by itself does not prevent random and radical changes in control-state policies—it just slows them down. However, there is considerable evidence that people do not choose control policies randomly or only according to external demands; rather, they seem to have individual preferences for particular control styles and default values that can be biased toward the persistence or the flexibility pole of the control dimension that I have suggested. Some of these preferences are likely to reflect genetic predispositions. There is considerable evidence that the genetic setup of individuals can have specific, selective effects on the efficiency of processing along the mesofrontal or nigrostriatal dopaminergic pathway, which has implications for people's abilities to engage in persistence or flexibility.

For instance, the COMT Val158Met polymorphism is known to affect frontal dopaminergic processing, which again has been assumed to shift the dominance in frontostriatal interactions toward the frontal system in some genotypes and toward the striatal system in others (e.g., Nolan, Bilder, Lachman, & Volavka, 2004). Indeed, individuals with a genotype favoring frontal dopaminergic processing were shown to have more difficulties switching from one task to another than individuals with a genotype favoring striatal dopaminergic processing (Colzato, Waszak, Nieuwenhuis, Posthuma, & Hommel, 2010). Interestingly, the same polymorphism also predicted the degree to which people benefit from playing video games: individuals with a genotype favoring striatal dopaminergic processing showed better transfer from a video game training to task switching (Colzato, van den Wildenberg, & Hommel, 2014). Other polymorphisms are known to affect striatal dopaminergic processing, which in turn is likely to shift the balance from or toward the striatal component of the frontostriatal interaction from the other side. For instance, genetic markers of striatal dopamine were shown to predict individual differences in the control of stimulus integration over time (Colzato, Slagter, de Rover, & Hommel, 2011), in the handling of integrated episodes (Colzato, Zmigrod, & Hommel, 2013), in attentional flexibility (Colzato, Pratt & Hommel, 2010) and functional impulsivity (Colzato, van den Wildenberg, van der Does, & Hommel, 2010).

While it remains to be seen whether and to what degree these genetic constraints and biases can be overcome, there is considerable evidence that personal experience, learning, and cultural embedding can affect and create apparently rather stable interindividual differences. In the following, I will first focus on short-lived biases of metacontrol states that not only provide evidence for the inertia of control parameters, but also demonstrate the usefulness of the MSM in accounting for intra- and interindividual differences in control policies under various circumstances. Then, before I close with a brief conclusion, I will turn to more durable biases and show that people can acquire particular personal metacontrol styles that predict important characteristics of their performance.

7. SHORT-TERM BIASES OF COGNITIVE CONTROL

One set of studies that have tested predictions from MSM with respect to short-term biases toward more maintaining or more flexible control states has used mood induction. The induction of positive mood has often be assumed to promote "loose thinking" and creative thought (Ashby, Isen,

& Turken, 1999), and there is considerable evidence that at least brainstorming-like divergent-thinking tasks benefit from positive mood (Baas et al., 2008; Isen, 1999). If so, one would expect that positive mood leads to a more "flexible" control state as indicated in Figure 1(d) and (e) (cf., Nijstad, De Dreu, Rietzschel, & Baas, 2010). Take, for instance, the Alternate Uses Task (AUT) often used to assess divergent thinking (Guilford, 1967). In this task, participants are presented with the description of a simple everyday item, like a pen, and are then asked to list as many uses they can think of within limited time. Such a task would require rather weak top-down support, as the search criterion is rather vague. Given that many answers are possible and correct, the competitiveness between alternatives should also be as weak as possible (i.e., just strong enough to select them sequentially). This means that performance in this task would strongly benefit from a control mode that is strongly biased toward flexibility. Accordingly, it makes sense that divergent-thinking benefits from positive-going mood.

These considerations are not limited to creativity tasks, so we can consider the implications of positive mood for other tasks as well. If positive mood would bias control toward more flexibility, it should increase the impact of goal-unrelated, irrelevant information and reduce the impact of top-down control. This is consistent with observations of Dreisbach and Goschke (2004), who found that the induction of positive mood is accompanied by less systematic attentional focusing and greater distractibility. Along the same lines, there is evidence that positive-mood induction reduces the degree to which task performance is monitored and adjusted in the face of internal conflict. It is known that, in tasks with conflicting stimuli, like Stroop or flanker tasks, the experience of conflict leads to a reduction of the impact of irrelevant information in the next trial—the Gratton effect (Gratton et al., 1992). According to Botvinick, Braver, Carter, Barch, and Cohen (2001), this is because the registration of multiple response activations (i.e., response conflict) is fed to frontal systems responsible for the maintenance of the action goal, and results in the reactivation/strengthening of the goal representation. This should increase the top-down control of information processing in the next trial, and thereby reduce possible conflict. Interestingly, the presentation of unexpected reward (van Steenbergen, Band, & Hommel, 2009, 2012) and the induction of positive mood (van Steenbergen, Band, & Hommel, 2010) effectively prevent this process of control adjustment, suggesting that positive mood indeed reduces the impact of top-down control. A recent neuroimaging study indicates that this reduction is caused by attenuating the response of the assumed conflict monitor (the anterior cingulate cortex) to stimulus-induced conflict (van Steenbergen, Band, Hommel, Rombouts, & Nieuwenhuis, in press). While positive mood reduces top-down control, negative mood leads to an increase: van Steenbergen, Booij, Band, Hommel, and van der Does (2012) tested the effect of dysphoria induced by acute tryptophan depletion in remitted depressed patients and observed a significant increase of control adjustment under these conditions.

Systematic mood effects were also obtained in dual-task contexts. For instance, Zwosta, Hommel, Goschke, and Fischer (2013) reported that the induction of negative mood led to a stronger shielding of the prioritized task (i.e., less cross talk) than the induction of positive mood, which fits with the idea that positive mood reduces top-down impact. Fischer and Hommel (2012) used a different rationale to investigate dual-task performance. They mixed the task with a creativity task that required either divergent thinking, as in the mentioned AUT, or convergent thinking, as in the Remote Associations Task (RAT; Mednick, 1968). This task provides more and rather tight top-down constraints, and there is only one possible answer per item (e.g., which word goes with "market," "man," and "glue"?), suggesting that the task calls for a control state with a strong impact of the goal—a bias toward persistence. If so, performing the RAT should increase top-down control and reduce cross talk in an overlapping dual-task, which is indeed what Fischer and Hommel observed.

So far, I have considered mood as an independent variable that biases cognitive control to a more persistence-supporting or a more flexibility-supporting state and task-related control-state configurations as the dependent variable. From a functional perspective, one might consider influence in the opposite direction as well. That is, adopting a control state close to the persistence pole of the control dimension might be associated with more negative mood than adopting a control state close to the flexibility pole. Akbari Chermahini and Hommel (2012b) tested this possibility by having participants perform convergent- or divergent-thinking tasks and assessing whether these tasks had an impact on mood. This was indeed the case: mood was improved by performing the divergent-thinking task and performing the convergent-thinking task had the opposite effect.

Another factor that has been found to have a systematic impact on cognitive control states is meditation. Meditation has been notoriously suspected to improve creativity, but systematic evidence regarding whether this is really the case is rare. We have pointed out that this is likely to be the case for two reasons (Lippelt, Hommel, & Colzato, 2014). For one, different kinds of meditation have different goals and use different techniques to achieve them. As pointed out by Lutz, Slagter, Dunne, and Davidson (2008), some techniques are coaching the meditator how to focus on one single thought while avoiding distraction (focused-attention meditation), while other techniques aim at teaching the meditator how to open up and to accept any thought that may come up at any time (open-monitoring meditation). It is unlikely that these two techniques are associated with the same cognitive control state; rather, it makes sense to assume that focused-attention meditation serves to bias cognitive control toward the persistence pole while open-monitoring meditation promotes flexibility (Lippelt et al., 2014). For another, creativity is not a unitary construct and comprises several components with partially opposite characteristics (Wallas, 1926; Guilford, 1967). In particular, some creativity tasks (like the RAT) are tapping more into convergent thinking while others (like the AUT) are tapping more into divergent thinking. If we consider the above reasons and evidence that convergent-thinking benefits from a persistence-heavy control state while divergent-thinking benefits from a flexibility-biased state, it makes little sense to assume that both kinds of thinking benefit from the same kind of meditation. Rather, focused-attention meditation should promote convergent thinking while open-monitoring meditation would be suspected to facilitate divergent thinking.

These predictions were indeed confirmed in studies that systematically compared the impact of focused-attention meditation and open-monitoring meditation on convergent and divergent thinking. In a study on meditation practitioners (Colzato, Ozturk, & Hommel, 2012) and a study comparing practitioners with meditation novices (Colzato, Szapora, Lippelt, & Hommel, in press), open-monitoring meditation led to a substantial improvement of divergent thinking without affecting convergent thinking. Focused-attention meditation in turn tended to improve convergent thinking without having any impact on divergent thinking. Why the impact of focused-attention meditation on convergent thinking was not statistically reliable is likely to due to the fact that most participants were students—who can be assumed to engage in convergent thinking on an everyday basis—so that their performance was probably at ceiling already.

A further line of research investigated whether control states might affect interpersonal processes. The rationale motivating this research is based on the assumption that people cognitively represent themselves and others like any other event (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Hommel, 2004): as a network of codes that represent various perceptual and conceptual features characterizing the event (for further discussion, see Greenwald et al., 2002; Hommel, 2013; Hommel, Colzato, & van den Wildenberg, 2009; Kim & Hommel, 2015). If this is the case, one would assume that a control state close to the persistence pole of the dimension should lead to a more pronounced discrimination between "me" and "other," because this control state is associated with maximal competitiveness between alternative representations. In other words, the mutually inhibitory links between the "me" representation and the "other" representation should be particularly strong, so that activating one should tend to inhibit the other to a maximal degree. In contrast, a control state close to the flexibility pole should lead to minimal discrimination, that is, to maximal interpersonal integration. In other words, this control state would propagate a view of me and other as one unit while a persistence-heavy control state would induce a more "individualistic" representation.

Along these lines, one would expect that engaging in activities that are likely to drive the control state toward persistence would reduce self-other integration, while engaging in flexibility-heavy tasks should have the opposite effect. This pattern of results was indeed observed by Colzato, van den Wildenberg, and Hommel (2013): Performing a divergent-thinking task was associated with a substantial increase in the joint Simon effect (Sebanz, Knoblich, & Prinz, 2003; for an overview, see Dolk et al., 2014), which indicates the degree to which participants are affected by the presence of another person working on the same task. The same effect was obtained by having participants to circle either personal pronouns (such as "I," "my," or "me") or relational pronouns (such as "we," "our," or "us") in a text (Colzato, de Bruijn & Hommel, 2012). In another study, engaging in divergent thinking was reported to increase interpersonal trust (Sellaro, Hommel, de Kwaadsteniet, & Colzato, 2014), and the same effect was obtained by exposing participants to the scent of lavender, which is assumed to induce a more flexibility-heavy control state (Sellaro, van Dijk, Rossi Paccani, Hommel & Colzato, 2014).

8. THE IMPACT OF LEARNING, EXPERIENCE, AND CULTURE ON COGNITIVE CONTROL

The evidence I have discussed so far shows that particular metacontrol states have a specific impact on internal representations and information processing. This impact was restricted to a temporal scale of seconds or minutes, and this is indeed a scale that is particularly likely to show such effects. As it is known from task-switching studies (see above), changing control states takes quite a bit of time and just-implemented states tend to be sticky to some degree, so that it makes sense to look for state-related aftereffects and cross talk in the range of minutes or seconds. And yet, it also makes sense to assume that longer-term effects and biases are possible. Consider the hypothesized metacontrol dimension ranging from extreme persistence and top-down impact to extreme flexibility and openness. There are certainly tasks and situations in life that call for control states that are more biased toward one than the other pole, but it is unlikely that there is a particular optimal value for each task or situation. As emphasized by Goschke (2003), some degree of goal-orientation/top-down control and some degree of flexibility will be necessary under almost all circumstances, which still leaves quite some range of possible values on the hypothetical dimension—not unlike the case of choosing between speed and accuracy. The existence of a range of possibilities creates uncertainty, which is commonly assumed to be aversive. This suggests that people seek ways to reduce uncertainty regarding metacontrol parameters. One way to reduce it is to adopt a particular default value, which an individual can use in all situations that do not require deviations from that value. Where do individual default values come from? Several options are possible and they are not mutually exclusive. In the following, I will discuss a few options that colleagues and I have addressed empirically.

One relates to personal conditions that are more compatible with one than with the other pole of the hypothetical metacontrol dimension. Engaging in a loving relationship is such a condition, as it is likely to promote positive feelings and general positive mood. If so, MSM would predict that passionate lovers are less efficient in maintaining tight action control. Indeed, van Steenbergen, Langeslag, Band, and Hommel (2014) observed that the intensity of passionate love as assessed by the Passionate Love Scale predicted the individual efficiency in cognitive control as measured in Stroop and flanker-task performance—with greater passion leading to less control.

Another way to influence cognitive control is learning. Colzato, van Leeuwen, van den Wildenberg, and Hommel (2010) considered that the new generation of "First Person Shooter" games may require players to develop a more flexible mind-set that allows them to engage in complex scenarios, to rapidly react to moving visual and sudden acoustic events, and to switch back and forth between different subtasks. If so, one would expect that extensive experience with such games should enhance cognitive flexibility and, indeed, players of such video games were found to be superior to nonplayers in a task-switching paradigm. While this study does not reveal whether and how performance in persistence-heavy tasks was affected, it does suggest that the flexibility part of control can be systematically trained. However, it must be noted that the study was correlational in nature, which leaves the possibility that players are a self-selected group with superior flexibility skills. It is also important to point out that task-switching paradigms are rather complex, and that task-switching performance arguably comprises both persistence and flexibility components.

Another example of learning-related changes in metacontrol abilities relates to bilingualism. There is considerable evidence that bilinguals not only outperform monolinguals in various language tasks (even though bilinguals can show poorer performance early in learning), but they show superior performance in a number of nonlingual tasks as well (for an overview, see Bialystok & Craik, 2010). These observations have motivated the view that acquiring a new language goes hand in hand with learning how to suppress conflicting information. In the learning process, this information will be mainly linguistic, such as the words and grammatical structures of one's native language. However, if we assume that discriminating between, and holding in check conflicting languages is a metacontrol process, it is very well possible that training and improving this process generalizes to the control of the processing of nonlinguistic material.

In a systematic comparison of tasks tapping into direct, "active" suppression (like the stop-signal task: Logan & Cowan, 1984) and tasks involving the inhibition of alternatives through the process of competitive selection, as discussed above, Colzato, Bajo et al. (2008) were able to show that it is only the latter, not the former process that bilinguals excel in. For instance, while bilinguals and monolinguals showed no difference whatsoever in the stop-signal task, bilinguals performed more poorly in the attentional blink task. In the attentional blink task, participants report the presence and identity of two targets presented in close succession. The term "attentional blink" refers to the common observation that both targets can be accurately reported with longer lags between them while the second target is often missed when the lag is short. This has been attributed to the processing of the first target, which seems to be so demanding that a second target cannot be considered before processing the first is completed (for an overview, see Hommel et al., 2006). Interestingly, however, there are considerable interindividual differences in the size of the effect (e.g., Martens, Munneke, Smid, & Johnson, 2006) and situational circumstances under which the "blink" of the second target can be avoided altogether (e.g., Olivers & Nieuwenhuis, 2006). Moreover, trials in which the second target is missed are characterized by a particularly large allocation of attentional resources to processing the first target (Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006), which suggests that the attentional blink phenomenon is due to too much top-down control (Olivers & Nieuwenhuis, 2006). If so, it makes sense that bilinguals, who have been claimed to acquire stronger top-down control (e.g., Bialystok, Craik, Klein & Viswanathan, 2004), exhibit a more pronounced attentional blink. It also makes sense that bilinguals outperform monolinguals in convergent thinking, but show poorer performance than monolinguals in divergent thinking (Hommel, Colzato, Fischer, & Christoffels, 2011).

Becoming and remaining a bilingual is certainly a long-term learning experience, but the learning process and the exercise are commonly much more socially embedded than mastering a video game. Given that the learning experience seems to affect people's personal control styles, we can hypothesize that societal practice and culture might contribute to the development and persistence of metacontrol styles. We pursued this possibility in a recent line of research that looked into the impact of religion on cognitive control. There is some evidence from cultural studies that metacontrol styles might be sensitive to the cultural environment in which people grow up. For instance, people growing up in North America have been shown to be less sensitive to contextual cues and show a more analytic cognitive style (i.e., to pay more attention to local features of objects and events) than people growing up in Asia, who exhibit a more holistic style (i.e., pay more attention to global features) (Nisbett & Miyamoto, 2005). The concept of culture is very hard to define, however, so that one, for instance, can argue whether all citizens of the United States really share the same culture and whether one can speak of a homogeneous Asian (or even "Eastern") culture. A similar concept that is easier to define is religion, and here I do not mean religiousness as such, but adopting a particular religious faith. Even though not all faiths are based on available holy scripts and rules, and even though the degree to which members of a religious community follow religious rules and regulations varies, some basic and widely shared rules and values can often be identified for at least some variants of religious conviction.

How might religion shape metacontrol? Hommel and Colzato (2010) have argued that many kinds of religious faith have characteristics that are likely to require a particular metacontrol style, so that adopting a particular faith is likely to lead to the establishment of metacontrol parameter defaults that are compatible with the required style. For instance, Dutch neo-Calvinism is built upon the concept of sphere sovereignty, which emphasizes that each sphere or sector of society has its own responsibilities and authorities, and stands equal to other spheres (e.g., Boesak, 1984). This implies that active Dutch Calvinists have been often socially rewarded for adopting a metacontrol style that emphasizes a rather independent view of the self. According to my reasoning, this should require a pronounced bias toward the persistence pole of the control dimension, which again implies strong reliance on top-down control, good shielding against irrelevant information and little distractibility, but also comparably less self-other integration and global attention.

In a first test of these ideas, we (Colzato, van den Wildenberg, & Hommel, 2008) compared Dutch Calvinists with Dutch atheists that were brought up in the same country and culture and were matched with respect to race, intelligence, sex, and age, in the global–local task developed by Navon (1977). This task assesses how fast people can process global and local characteristics of hierarchically constructed visual stimuli (e.g., larger symbols made of smaller symbols). Typically, this task gives rise to the "global precedence" effect, which demonstrates that global features can be processed faster than local features—presumably due to a mixture of physiological and attentional factors. We were particularly interested in the size of this precedence effect. If Calvinists would be more oriented toward local details, their precedence effect should be small, meaning that they should not be much slower to report local than global stimulus characteristics. In comparison, atheists should show a larger precedence effect, that is, a more pronounced delay in reporting local as compared to global characteristics. This is indeed what we observed. A follow-up study replicated the effect and showed that the attentional control characteristics of baptized atheists (i.e., individuals raised as Calvinists, but no longer believing or engaging in religious practices) are indistinguishable from that of practicing Calvinists (Colzato, van Beest et al., 2010). This suggests that early practice in living a particular faith is more important than continued practice—chronic metacontrol parameters seem sticky. The same study also demonstrated that Italian Roman Catholics and Israeli Orthodox Jews (i.e., members of religions that emphasize social responsibility and interrelatedness of all societal aspects) show the opposite effect than Calvinists do (i.e., the global precedence effect was more pronounced in the religious groups than in matched atheist groups), as our approach would predict. Along the same lines, Colzato, Hommel, van den Wildenberg, and Hsieh (2010) reported a more pronounced global precedence effect in Taiwanese Buddhists (i.e., members of a religion that also emphasizes social interrelatedness) than in matched Taiwanese atheists. Taken together, these observations rule out that religiousness as such, or some correlated behavioral or personality feature accounts for our findings. Instead, it seems to be the particular religious practice that creates chronic metacontrol parameter values (Hommel & Colzato, 2010).

A further study showed that religious faith not only affects attentional control, but the sensitivity to task-irrelevant information as well. According to the MSM, Calvinists would be expected to show particularly low sensitivity to task-irrelevant information while Catholics should show particularly high sensitivity. Hommel, Colzato, Scorolli, Borghi, and van den Wildenberg (2011) tested this prediction in a Simon task that assesses the degree to which response selection is affected by irrelevant stimulus information. While Dutch Calvinists showed a less pronounced Simon effect than matched Dutch atheists, Italian Catholics showed a more pronounced Simon effect than Italian atheists—which confirms expectations. A further study tested the prediction that Calvinists would show a particularly large attentional blink. Recall that the attentional blink has been attributed to too much top-down control, suggesting that religious practice that emphasizes top-down control, as Dutch Calvinism does, should increase the effect. This is indeed what Colzato, Hommel, and Shapiro (2010) demonstrated. Finally, Colzato et al. (2012) investigated the impact of Buddhism on self-other integration. As explained in the previous section, self-other integration can be expected to increase to the degree that control states approach the flexibility pole. If so, practicing Buddhists would be expected to show more pronounced self-other integration than atheists, and one major aim of Buddhist practices is indeed to overcome the separation of self and other (Dogen, 1976). Colzato et al. tested this hypothesis by comparing Taiwanese Buddhists with matched Taiwanese atheists in a joint Simon task. As predicted, Buddhists showed a more pronounced effect, suggesting stronger self-other integration.

As pointed out already, religious practice is an example of a relatively well-defined social activity that is likely to shape the behavior of the involved individual. But it is not the only example. Another is membership in a relatively coherent minority group. To investigate whether such membership can also have a long-lasting impact on cognitive control, we compared homosexual and heterosexual individuals in a global–local task (Colzato et al., 2010). Our theoretical vantage point was speculation about the possible existence of some kind of "gaydar" (Reuter, 2002), an assumed special skill of homosexual individuals to detect the sexual orientation of others. Previous studies have revealed that homosexual participants are indeed better than heterosexuals in detecting the sexual orientation of strangers shown on photographs or in short movie clips, but this advantage disappears with slightly longer movie clips (Ambady, Hallahan, & Conner, 1999). We took this outcome pattern to rule out differences in knowledge about visible cues signaling sexual orientation, such as clothing, hair dress, or gesture. Instead, homosexuals might check for such cues more actively, as they rely more on them to identify possible partners. If so, the default control setting of homosexuals might be more biased toward local aspects of stimulus events, as this is the setting they are using more often than heterosexuals—at least for the purpose of partner identification. We tested this possibility by presenting homosexuals and heterosexuals with the global–local task. As expected, homosexuals had a smaller global preference effect than heterosexuals, which indicates that they have a relative preference for the processing of local stimulus aspects.

9. CONCLUSIONS

The main aim of this article is to point out that action control is unlikely to be a unitary function, but rather emerges from the interaction of two counteracting forces, one propagating a strong top-down control of information processing and the other opening up the system for alternative options and novel information. As I have argued, this more dynamic metacontrol approach has functional and neural plausibility, and is consistent with recent functional and neuroscientific insights. In this article, I did not focus on the neuroscientific evidence, but rather tried to show that a relatively simple functional model is sufficient to account for various phenomena indicating the existence of short-term biases of cognitive control styles and long-term chronic biases associated with particular kinds of experience and cultural context.

Even though the MSM I proposed has two components, these components are different from those considered by traditional dual-pathway models. The latter assume that the two alternative or conflicting pathways differ with respect to their reliance on familiarity and previous experience, their controllability, and their mechanisms. The MSM does not assume any of those differences and it in particular does not consider a stronger contribution of the nonfrontal component reflecting less control. Nor does it consider control configurations that leave space for other than goal-related top-down information necessarily inefficient or dysfunctional. The idea that more top-down control is better, as implicit or even explicit in many dual-pathway approaches, is in fact not particularly realistic outside of the psychological laboratory. In the absence of an experimenter who has already limited the available possibilities to exactly one task, one or two stimuli, and one or two predefined responses mapped upon them, a human agent is always facing the possibility that the current task is not the most important, most appropriate, most efficient, and most successful, which requires the continuous monitoring for interesting alternatives. Switching off processing channels busy with these considerations might buy a few milliseconds, but could have fatal consequences.

MSM can also do without an ego or agent and without a dedicated inhibitory system. Inhibition emerges through competition and, thus, does not require loans of intelligence to explain how inhibitory systems know which representations to target. The main intelligence in the control system that calls for explanation is the choice of metacontrol styles: why does control sometimes lean toward persistence and sometimes toward flexibility, and what are the criteria for changing this policy? I have tried to reduce this loan of intelligence as well by considering genetic reasons for individual differences and by showing that individuals can acquire chronic default values through cultural learning and other kinds of personal experience. The remaining flexibility that people do seem to have might be explained by considering situational cues and immediate feedback, but certainly more research will be necessary to unravel the details of these processes. Moreover, it is fair to say that the MSM is currently more of a heuristic tool rather than a formalized theoretical framework, and making progress on this will require much more fine-tuning. Nevertheless, I am convinced that considering the dynamic, interactive nature of cognitive control will deepen our insight into the mechanisms underlying the emergence of human behavior.

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