The Executive Ghost in the Machine: On the Twin Follies of Frontal Lobology and Central Executivism

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Abstract. This position paper argues that research on intelligent, goal-directed cognition has been hampered by two related tendencies. The first of these, frontal lobology, is to explain almost all complex human behavior as being due to activity of the frontal lobes of the brain. The other, related tendency, central executivism, is to take a black-box approach to understanding top-down cognitive mechanisms, explaining seemingly all adaptive, intelligent behavior as being due to 'executive function'. These intertwined approaches both suffer from similar problems, such as gross oversimplification, combining diverse phenomena under an umbrella term, and committing logical fallacies, particularly the personification of cognitive processes as a homunculus in the brain and mind. We argue that a greater focus on brain-wide networks underlying goal-directed cognition, beyond the frontal lobes, particularly recognizing partially-open prefrontal-subcortical circuits is needed. This needs to be combined with recognition of diverse, potentially independent manifestations of cognitive control. We argue this will provide a more fruitful avenue for research in cognitive sciences, generating hypotheses that could be tested through experimentation or formal methods.

Keywords: Executive function · Supervisory attentional system · Cognitive control · Working memory · Central executive · Frontal lobe · Prefrontal cortex · Goal-directed behavior · Formal methods.

1 Background

Neuroscience has advanced substantially in recent decades. A major driver of these advances has been new technology, particularly brain imaging methods, such as MRI, combined with ever powerful computing power to process the signals. However, it is becoming clear that until recently the interconnectivity [1], and overall complexity of the neural processes underlying cognition has been

grossly underestimated [2]. Similarly, AI, in the form of language and image generative models, has recently led to multiple advances in cognitive science.

In stark contrast, there is continuing tendency to provide explanations of human behavior using extremely simple cognitive and neurological concepts. Invoking neuroscience there is a widespread tendency to explain almost all behavior as being controlled by the frontal lobes of the brain, a practice that has been called *frontal lobology* [3,4]. Closely related to this, the functional equivalent is to explain almost all deliberate behavior as being controlled by an executive cognitive process, a practice we have dubbed *central executivism*. The two issues are intertwined, as these two approaches both include the assumption that the central executive controller has as its physiological substrate the frontal lobes of the brain.

The concept of an executive controller is central to several influential cognitive theories [5,6,7,8,9]. Although, there are some differences between them, the fundamental assumption of each is that there is a limited-capacity core processor in the frontal lobes of the brain that provides top-down control of more basic cognitive processes. That controller is active when routine processing would not produce adaptive behavior, such as decision making under uncertainty, problem solving, controlling impulses, and responding to novel situations [10,11]. Tests of ability designed to measure executive function can predict a range of real-life behaviors ranging from misbehavior of school children [12], performance of car salesmen [13] and a range of health and social outcomes [14]. These tests are often described as frontal lobe tests, or executive function tests.

1.1 Our Position

It is our position, that the entwining of the concepts of frontal lobe function and executive function is overly simplistic, and furthermore, both concepts are too general and too poorly specified. At the very least, greater progress could be made if more specific theories and descriptions are adopted.

Nevertheless, unnuanced explanation of behavior by describing it as being caused by activity of the frontal lobes (frontal lobology) or by an executive controller (central executivism) remains rife among a range of sciences that deal with human behavior.

In this paper we analyze the problems with these approaches, leading to some suggestions for a more appropriate way forward. However, first, we describe the historical development of the central executive concept and its links to the frontal lobes of the brain. This leads us naturally into the current issues.

2 Development of the Concept of a Frontal-Lobe Central Executive

The concept of an executive controller of behavior has its origins in computer science, as many control programs, essentially batch filers, were developed to control early digital computers in the 1950s and 60s. These had names such as

the General Motors Executive System, the Executive, Exec 1, and the Supervisory Control Program [15,11]. This emphasis on the higher-level control of basic computational process was integrated into neuroscientific explanations for the functions of the primate frontal lobes by the neuroscientist Karl H. Pribram [16]. Drawing on computer architecture of the time that required a "'working" or temporary memory' [16, p. 49], Pribram suggested the frontal lobes may have that role. Still inspired by computer science, he later explicitly named these neurological processes in the frontal lobes as 'executive programs' [17].

The concept was also adopted by cognitive psychology. Only a year after Pribram's 1973 paper linking the frontal lobes with executive programs, Baddeley and Hitch proposed a purely functional multi-component model of human memory which contained two short-term memory stores and a component named the central executive [6]. Baddeley argued that the central executive has ultimate control over the functioning of short-term storage. However, the central executive concept was later directly adopted, under a new name—the Supervisory System—as the ultimate, top-down cognitive controller of goal-directed behavior in general [8,9], meanwhile, Baddeley similarly extended his concept of a central executive [18] tacitly placing it at the top of a cognitive hierarchy.

As would be expected, more recent researchers have attempted to map the cognitive model of working memory onto brain structures. As with the early theory of Pribram, the supervisory central executive has been explicitly placed in the frontal lobes [19,20,10,9]. Thus, the concept of a central executive cognitive controller, located in the frontal lobes, has become one of the most highly researched topics in cognitive and brain sciences.

The concept of an executive, of course, conjures the image of a masterful, managerial individual that has the power to take decisions, push plans forward, cancel them, and generally control the lower-level administrative processes. An alternative metaphor sometimes used is the CEO of the frontal lobes [21], or even the orchestral conductor [22]. An artistic representation of this cognitive personification is shown in Fig. 1. It has been said, somewhat tongue-in-cheek, that this god-like figure represents the only cognitive construct capable of good or evil [23].

There are multiple problems with this approach, spanning neuroscience and analytical philosophy. For convenience, we can group these criticisms into two broad types, on the one hand focused on the theoretical and philosophical aspects, and on the other on the physiological aspects. We will first examine the latter, that is, the problems with explaining control of goal-directed behavior as 'frontal lobe function'.

3 Frontal Lobe Processes as the Basis of Executive Function

Although early digital computers did use programs that could be reasonably described as being executive, or supervisors [15,24,11], and the computer analogy has undoubtedly been productive in driving cognitive science since its inception

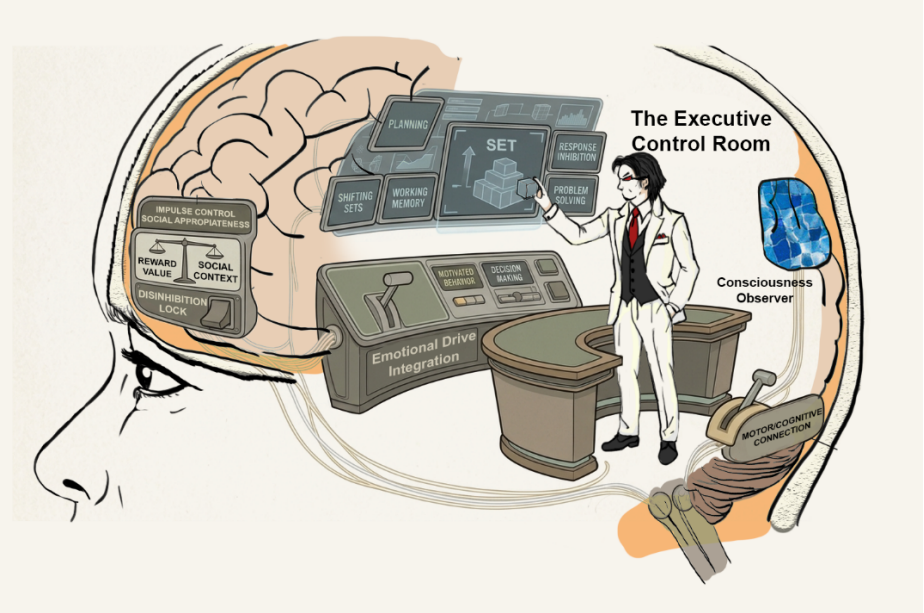

Fig. 1. The Central Executive is frequently argued to be located in the frontal lobes and personified as a powerful business executive, working to manage an organization.

in the 1950s [25], it is questionable whether equivalent unitary executive systems can be located in human brains. Aside from the different processing requirements, it is arguable that brain computation has a fundamental functional advantage over other forms of computation [26]. Thus, using electrochemical processing, as used in human brains, has led them to being dubbed *meat machines*, to distinguish them from silicon-based digital computers that work in fundamentally different ways [27]. Accordingly, multiple cognitive and neuroscience research groups have expressed a need to move away from the computer metaphor for understanding the functions of minds and brains [28].

Whether computational functionalism between digital computers and meat machines is sufficient to justify the analogy is beyond the scope of this paper. The point being made is that location of discrete processes to discrete human brain regions, such as the frontal lobes, is fraught with difficulties.

3.1 Physiological Considerations

A main problem is neural processing generally does not respect lobular boundaries. Whereas the left and right lobes of the brain are physically separated from each other by the connective tissue of the falx cerebri, the neural tissue of the lobes within hemispheres is contiguous. The anatomical distinction between the different lobes is based mainly on visible features that can be used as convenient boundaries, the lobes themselves are named after the bones of the skull that lie

above them. Technically, each of the two frontal lobes is identified as the tissue anterior to the central sulcus and superior and medial to the Sylvian fissure (see Fig. 2). The cortex of the frontal lobe is not only physically contiguous with the tissue of adjacent cortex; it is also functionally interrelated. This is confirmed by the presence of multiple short fiber connections, linking frontal and non-frontal areas that are just millimeters apart [29].

Data from the Human Connectome Project demonstrates that brain activations associated with common executive function tests do not map onto discrete frontal subregions but instead converge within multiple domain-general cortical territories distributed across frontal, parietal, and temporal cortices, with the strongest peaks occurring at network borders rather than within lobular boundaries [30]. Furthermore, studies of patients with brain damage have sometimes failed to detect any executive function impairment specifically linked to lesions in the frontal lobes [31].

It is of course still possible that a modular central executive could be located squarely within either or both of the frontal lobes. And indeed, activation studies using brain imaging during task performance do tend to show predominantly bilateral activations within the cortex of the frontal lobes [32]. However, tasks that appear to recruit executive control, also appear to involve the highest level of connectivity between different brain regions [1], suggesting processing well beyond the boundaries of the frontal lobes. Indeed, neural connectivity studies identify many of the executive regions of the frontal lobes as part of the brain's rich club—the name given to areas that are most richly interconnected with other, distant brain regions [33].

In fact, attempts to localize functions to subregions of the frontal lobes have generally failed. Whereas in the posterior parts of the cerebrum (i.e., the occipital, parietal and temporal lobes) there is clear evidence of localized, modularity of functions [34], this seems to break down in the anterior regions (i.e., the frontal lobes). Analysis of activation patterns of frontal brain regions suggests that distributed functional networks underlie information processing, but there are no clear subregions associated with discrete cognitive processes [35]. And activations related specifically to the central executive, or areas that when damaged produce impairment of executive control, are widely distributed across the brain [36,37].

One reason for this is that the frontal lobes do not function through physiologically isolated processes. In fact, partially-open circuits involving the frontal cortex and deep, subcortical brain regions, particularly the thalamus and basal ganglia, likely underlie the supposed 'frontal' executive functions [38]. Together these frontal cortex and subcortical regions comprise a large part of the rich club of brain regions.

In particular, the frontal lobes appear to function substantially via recurrent loops between their cortices and subcortical structures which project back to the original cortical region, known as higher-order circuits. Importantly, these loops are not strictly hierarchical; activity that originates early, either cortically or subcortically, can drive recurrent activity in the loops [21]. This includes purely

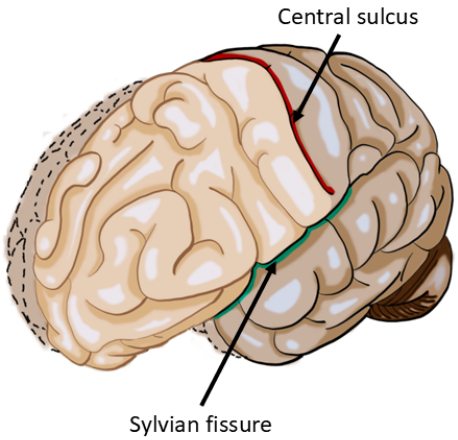

Fig. 2. The human left frontal lobe is highlighted here, delineated at the cortical level by the central sulcus and the Sylvian fissure. Together, the two frontal lobes comprise approximately one-third of the total brain tissue.

subcortical origins of activity in higher-order circuits [39]. This suggests that frontal lobe cortex should not be considered as working only top-down, but as part of an interaction between frontal cortical and deep subcortical structures.

Consequently, looping activity between frontal lobe and subcortical structures appears to underlie the type of deliberate behavior described as being controlled by a frontal central executive. In fact, the loops have long been known to be open-circuits, receiving input from a range of subcortical and non-frontal cortical regions, particularly the parietal lobe [40]. It has been estimated that for a human to produce one of the simplest deliberate movements, a voluntary finger lift, would require at least 20 cycles of a frontal-subcortical loop [41].

3.2 Frontal Lobology

Despite the physiological evidence that the frontal lobes process information as parts of distributed networks that include many non-frontal regions, it is extremely commonplace to hear of behavior being described as 'frontal lobe'. This is common in the mass media. For example, recently, several news outlets have run stories about 'frontal-lobe breakups'—why the frontal lobes may be responsible for the failure of romantic relationships. When celebrities such as Kanye West and Roseanne Barr have made racist comments, the media have argued it may be due to frontal lobe impairment, and frontal lobe maturation was used to explain why one pop star (Alameda) developed confidence, and in a different article, why a different pop star (Rachel Chinouriri), developed self-doubt.

In academic literature, the supposed disorganized behavior of people experiencing homelessness has repeatedly been explained by their frontal lobes not functioning sufficiently well [4], as has the behavior of people who acquire credit card debts [42]. Virtually all mental illnesses have been described as fundamentally being caused by frontal lobe dysfunction [3,43], and it has been identified as a major cause of criminality so frequently that lawyers often use a 'frontal lobe' defense [44]. It appears that almost any behavior can be explained by the frontal lobes either functioning well, or not.

The widespread use of the frontal lobe explanation for almost any behavior deemed dysfunctional, or successful, led the psychiatrist Anthony David to propose the concept of frontal lobology, which he argued is a pseudoscience [3]. However, the concept of frontal lobology has also been applied to neuroimaging [45], and social neuroscience research [4], and indeed is applicable to a large range of fields that invoke the frontal lobe as being a cause without fully examining the subprocesses and wider context.

One practical issue is that, assigning functions to the frontal lobes is highly imprecise regarding localization. Approximately a third of total brain tissue is part of the frontal lobes [46]. Localizing a function to the frontal lobes, would be equivalent, in geographical terms, to describing the location of a country by saying that it is in the Europe/Asia region. Furthermore, given a third of the human brain is frontal lobe, and it is highly interconnected with the other two-thirds, it is likely to be involved in some way with much of the processing undertaken by the whole brain.

It may be true, and probably is, that many executive control functions require cognitive processes that involve the frontal lobes. However, when behavior is explained as being due to frontal lobe activity, without consideration of the wider neurological and computational context, the explanation veers into pseudoscience. It is this unnuanced, facile, labeling of behavior as being 'frontal lobe' that marks the discourse as being potential frontal lobology. And, even if executive functions are causally linked to frontal lobe processes, there are fundamental, philosophical issues with explaining behavior through invocation of a central executive. This is the concept that we dub central executivism and will be discussed in the next section.

4 Executive Control of Behavior

The concept of an executive controller developed in cognitive and neurosciences because it was observed that models of performance that postulated obligatory processing within cognitive modules seemed to fail when explaining real world human behavior. The main promoter of the central executive concept in cognitive psychology, Alan Baddeley, was concerned that early cognitive models of memory developed in the 1960s, such as the Modal Model [47], lacked flexibility because they postulated memory stores that either stored or failed to store material, but lacked external control processes.

Baddeley and colleagues, for example, showed that tasks that loaded short-term verbal memory had little influence on ability to remember concurrently studied lists of words, suggesting the capacity limits could be circumvented in some way, such as by a central executive that prioritized processing depending on performance needs [48]. Similarly, from clinical neurosciences it was shown that some patients with memory disorders had impaired short-term memory capacity for both verbal and visual stimuli but nevertheless normal performance on a task requiring automatic recall after a delay [49], again, a result that could be explained if a central executive was included in the model.

In addition, there were several reports of patients with damage to their frontal lobes who developed disorganized behavior, but appeared to show no impairments on standard tests of cognitive ability, often even maintaining superior IQ scores [50]. It was argued that their impairments were limited to top-down control (i.e., executive) of lower-level cognitive processes that remained unimpaired. Hence, their disorder was named dysexecutive [51].

Although this has been a productive avenue of research, in that it explains a range of findings in neuroscience and psychology [11,13,12,50,49] the evocation of a central executive that controls lower-level cognitive processes has more than a whiff of personification, presenting some philosophical problems. These are explored in the next section.

4.1 Philosophical Considerations

That the central executive has been imbued with human qualities is evident even in the name, evoking ideas of an agent that coordinates behavior, making choices, and responding to changing demands. As discussed in the previous sections, such executive control has become so associated with the brain's frontal lobes, that the terms 'executive function' and 'frontal-lobe function' are frequently used interchangeably.

Is it right to say that the frontal lobes can make decisions? The philosopher P.M.S. Hacker and the neuroscientist Max Bennett have argued that neuroscience often makes what they call a mereological fallacy [52]. That is, to ascribe behavior that can be seen in an individual, to a part of an individual that is not truly capable of such behavior alone. Stating that the frontal lobes can perform like an executive appears to be a good example of this fallacy. Does it make sense to say that an executive in the frontal lobes can plan, take decisions, trouble shoot, and resist temptations—all behaviors attributed to them [8, p. 22]?

By definition, stating that the frontal lobes perform executive tasks such as planning and decision making involves the mereological fallacy, as the only type of thing that can be an executive, a person, can perform such executive tasks. The mereological fallacy is arguably an example of a category mistake, as used analytically by Gilbert Ryle in his book, *The Concept of Mind* [53]. It mistakenly compares activity in the brain as a category, with behavior of the individual who has that brain as a category. This is of course related to the category error argued by Ryle in which the mind is treated as a separate category rather than aspects of behavior and neural processes.

Ryle's critique of Cartesian dualism, as implying 'the ghost in the machine' is certainly relevant here. Cognitive theories that invoke a central executive controlling other cognitive processes appear to be supporting a form of Cartesian dualism by proposing an executive ghost in the meat machine. They may not realize it, many cognitive scientists ostensibly reject dualism, nevertheless it has been noted that both cognitive neuroscientists [54] and cognitive psychologists [55] readily slip into discussing the mind in dualistic terms, revealing implicit dualistic assumptions.

The problem that belies dualism, as stated by Ryle, is when explanations of behavior require an intellectualist legend. That was his term for the situation in which theories explain intelligent acts as being driven by internal acts of similar intelligence, which themselves require internal acts of intelligence, setting up an infinite regress. The infinite regress that is most obviously set up when proposing a central executive is that caused by presuming a homunculus in the mind, or in some versions, in the frontal lobes of the brain.

A homuncular argument is one in which a being is implied that performs the tasks that one is attempting to explain. That cognitive theories frequently involve unhelpful homuncular arguments has been raised several times. Most notably, Marr's seminal work on object recognition, which included production in the mind of a 3-D representation [56], was criticized as requiring a homunculus to see the representation [26]. This is clearly a problem for cognitive explanations of behavior that suggest that the processing is done by an executive. This folly is incredibly common within the cognitive sciences, interpreted broadly. Much research concludes that a given behavior is, or is not, influenced by executive control, or that non-adaptive or dysfunctional behavior is caused by executive failure.

The problem arises when behavior is being explained by the behavior of a different mechanism with the same properties. In this case behaving like an executive (e.g., decision making, planning) is being explained by an internal homuncular executive that is capable of decision making and planning. This then begs the question of who is doing the decision making and planning in the mind of the homunculus? One can only presume another homunculus. This recursion of function produces an infinite regress. Of course, such an infinite regress is a logical fallacy and useless as an explanation of cognitive processing. This infinite regress is represented visually with our internal homuncular executive in Fig. 3.

That the central executive of models such as Baddeley's multistore model appears to represent a homunculus is not a novel observation, and has been argued many times over past decades [57,36]. However, it is a criticism that remains as valid now as it was in the past. This brings us onto the next section, the over reliance on explaining behavior through a poorly-defined executive in the cognitive system. We have named this problem central executivism.

4.2 Central Executivism

The concept of a central executive or executive supervisor is used to explain a wide range of phenomena. It is argued, for example, that executive dysfunction

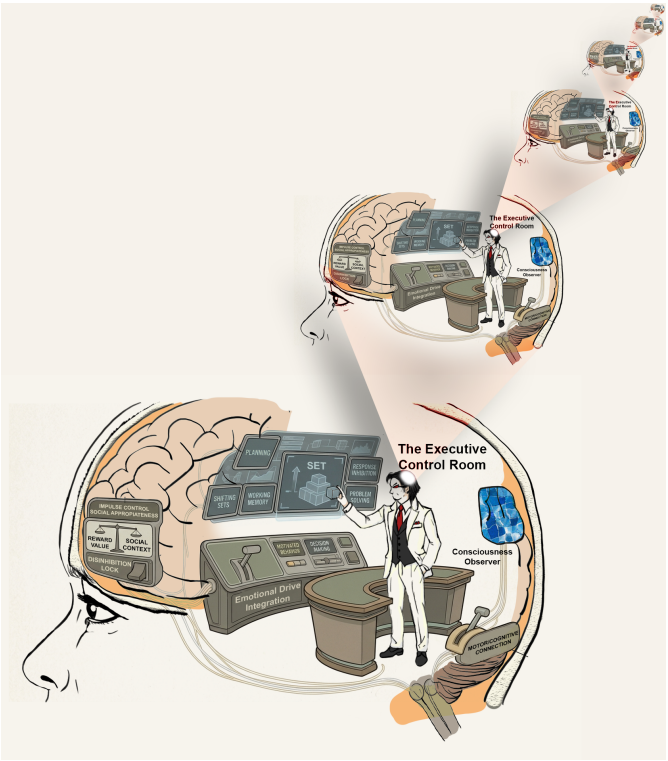

Fig. 3. When a homuncular executive is postulated to explain behavior, the theoretical consequence is an infinite recursive loop, as each homunculus requires another to explain its behavior.

is observed in virtually all mental health disorders and drives the social and occupational impairments associated with the illnesses [58,59]. Other real-life factors linked to strengths and weaknesses in executive control include obesity, overeating, medication adherence, overall quality of life, academic attainment, workplace performance, job stability, success of one's marriage, crime, anti-social behavior, and emotional stability [14]. And grandly, it is argued that executive function is the neural and cognitive foundation of human culture [60].

How can one discrete cognitive module be responsible for so much of human life? Part of the problem is that the role of the central executive is so loosely defined that it potentially includes any cognitive processes not deemed to be implemented automatically. Within behavioral neuroscience, a fundamental distinction exists between goal-directed operant behavior and habitual behavior [61]. These concepts are equivalent to the distinction between model-based and model-free processes in artificial intelligence [62]. Executive control appears to match directly onto the model-based or goal-directed aspect [63]. Any behavior that is not habitual or reflexive, therefore, can be potentially interpreted as mediated by a central executive.

In addition to its over-inclusiveness, executive control is often used in explanations that are circular, which over emphasizes its predictive power. As an example, the disorder ADHD is medically defined by the presence of inattention, disorganized behavior, and impulse control problems [64]. These are behaviors that would be defined in terms of executive control. Of course, data collected using an executive model supports the 'executive theory of ADHD' [65]. These circular associations contribute to the belief in the importance of executive processes in the overall cognitive system.

The concept of a centralized executive controller is over inclusive because it is treated as if it were a discrete processing module, responsible for all top-down cognitive control. However, this is true neither at the neurological nor functional levels. Neural tissue associated with executive processing is found in many parts of the brain [30,32,36]. And task demands that appear to require a central executive, such as doing two things simultaneously, appear to be unrelated to top-down executive control [7,66], while executive control of semantic information appears to be somewhat independent of non-semantic executive functions [67,68]. In fact, performance on diverse tasks said to measure executive functions may be uncorrelated with each other [23]. At best, multiple different assumed cognitive abilities, such as inhibition, updating working memory stores, and switching focus, share some common processing, while also being at least somewhat computationally independent [7]. The evidence does not support the existence of a singular, central executive [36,37].

To be fair to the main originators of the concept of a central executive / supervisory system in cognitive sciences, both Alan Baddeley and Tim Shallice have long argued that the executive fractionates into separable processes [48,69]. However, in practice, thousands of researchers have conducted research and published theoretical studies about 'executive function', overtly treating it as a single, modular cognitive process. This may be because both Baddeley and Shallice

continue to describe the executive component within their models as a singular model component (it is still presented this way in the latest versions of their cognitive models) [5,9]. Part of the vagueness may be due to the visual nature of the models, typically represented as box and arrow diagrams, with *the* executive in its own box. While box and arrow diagrams are undoubtedly useful in representing interactions of processes within computer science, within cognitive sciences the executive box has been treated as a black box, with little attempt to specify or understand the processes within it.

We argue that the concept of a centralized executive controller is over used in practice, without sufficient nuance, leading to a dizzying array of phenomena being described as due to executive control. This central executivism is twinned with the equivalent issue at the neurological level, frontal lobology.

5 Summary and Ways Forward

It is all too easy to describe some behavior or cognitive process as being due to the physiological activity of the frontal lobes of the brain. Substantial and mounting evidence suggests instead that processing associated with executive control involves networks that are widely distributed across the brain, including many non-frontal regions. In addition, and closely related, it can be tempting to invoke a homuncular central executive, supposedly located in the frontal lobes, as an explanation for a wide range of human behaviors. We argue that these ways of interpreting goal-directed behavior, which we have called frontal lobology and central executivism respectively, are academic follies.

5.1 Possible Solutions

The issues that we have identified do not represent insurmountable obstacles to progress. Regarding the tendency to explain complex human behavior as being 'frontal lobe', a better way forward is for those writing on these matters to use more precise descriptions. There are around 850 unique structures identified in human neuroanatomy [70]. In addition, there are widely-used directional systems used to describe specific areas of structures, meaning many thousands of anatomical labels are available. More precise use of anatomical language would prevent some from falling into frontal lobology. Additionally, specifying the suspected interconnections or functional networks identified through neuroimaging would tend to be more accurate than specifying by lobe. This is basically a call for more use of a systems neuroscience approach, as opposed to the traditional single-region localizationist approach in cognitive neuroscience. The multiple-demand system identified in the primate brain, which appears to be involved with many functions described as executive [30], is a good example of this. The various parts of the system across the brain are well defined [32].

The second folly identified, central executivism, can similarly be avoided by recognizing that the expression 'executive', although it may have some heuristic value, is basically an umbrella term. Cognitive scientists can, and do, attempt

to understand the subprocesses within different goal-directed behaviors. To be fair, some researchers have earnestly attempted to break down the subprocesses described as executive, with some success [71,37,72]. Related to this, the use of an executive black box within diagrams of cognitive models may be best avoided.

In fact, the concept of a central executive could be replaced with more accurate, less homuncular terminology. Within neurosciences, it is relatively common for the expression cognitive control to be used to describe the top-down influence of control processes on lower-level cognitive processes. The concept of cognitive control is virtually identical to what is meant by executive function [10]. However, the former lacks the assumption of a central process applied across cognitive domains, which is the error within the concept of a central executive. We believe that the simple vocabulary change from executive to cognitive control would prevent some of the currently widespread unintentional neglect of the diversity and complexity of the processes involved in top-down organization of processes underlying intelligent behavior.

Theories of cognitive control that avoid treating processes as a black box, and suggest processes in the human mind, are already available. As an example, John Duncan has published several theoretical papers describing how intelligent executive control can be decomposed into separable cognitive processes [73,74]. His work has also linked cognitive control to a network across multiple brain regions [32]. Other theories have also, to some extent, delineated different 'executive' processes based on psychological research [7,11,71,72].

Formal methods can potentially be used to test and compare different theories derived from psychological data. We have begun this process, using formal modelling of executive and working memory processes [75,76]. This is not currently a common research practice, but shows great potential for advancing our understanding of cognitive control mechanisms.

5.2 Conclusions

Much research on the control of behavior has embraced the concept of an executive, presumed to reside in the frontal lobes of the brain. However, the physiological evidence suggests that is a gross oversimplification, and at the functional level, the concept of an executive suffers from being a homuncular explanation. We have termed these dual follies frontal lobology and central executivism. It is our position that a greater focus within cognitive science on the actual cognitive mechanisms allowing cognitive control will allow a more coherent understanding of intelligent, adaptive behavior.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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