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Executive Functions and Attention Deficit Hyperactivity Disorder: Implications of two conflicting views

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While increasing numbers of articles and books refer to Attention Deficit Hyperactivity Disorder (ADHD) as a disorder of “executive function” of the mind, two conflicting views have emerged about how ADHD and executive function are related. In one view it is argued that some, but not all, who meet the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* diagnostic criteria for ADHD suffer from significant impairments of executive function. The alternative view holds that all individuals with ADHD suffer from significant impairment of executive function, and that ADHD essentially is a developmental impairment of executive function. These conflicting viewpoints rest upon divergent understandings of the nature of executive functions and how these functions should be assessed. Each leads to a very different conclusion about the essential nature of ADHD and its relationship to other learning and psychiatric disorders. This article describes and evaluates those two views and their implications.

Keywords: *Attention Deficit Hyperactivity Disorder; Conflicting views; Executive functions*

For decades after its initial description in the medical literature (Still, 1902), the disorder currently known as Attention Deficit Hyperactivity Disorder (ADHD) was understood as essentially a disruptive behaviour disorder. Often referred to simply as “hyperactivity”, the diagnosis was used to characterise children, almost exclusively little boys, who seemed unable to sit still, listen to adults, and refrain from disrupting their school classrooms. The first major change in official conceptualisation of the disorder came in 1980 when the third edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III) (American Psychiatric Association, 1980) altered the

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name of the diagnosis to highlight attentional impairments as the central feature. Work by Douglas (1988) and others had elaborated on a wide range of cognitive impairments found in those with ADD. Subsequently, Lahey, Schaughency, and Hynd (1987) and Lahey et al. (1988) described similarities and differences between those whose attentional impairments were accompanied by pathological levels of hyperactivity/impulsivity and those whose chronic attentional difficulties did not include significant behavioural problems.

Although DSM-III identified the diagnosis as “Attention Deficit Disorder,” it continued to list it in the category “behaviour disorders” along with Conduct Disorder. The 1987 revision of the *Diagnostic and Statistical Manual of Mental Disorders*, namely DSM III-R, rescinded the primacy of “attention” in this diagnosis by merging “attention deficit” and “hyperactivity” into equal status for the name of the disorder, and it was listed there as one of the disruptive behaviour disorders (American Psychiatric Association, 1987). While the 1994 revision restored recognition of a subtype of the disorder that includes little or no difficulty with hyperactivity/impulsivity, it continued the linkage of the two symptom sets with just a slight modification in punctuation and continued placement with diagnostic criteria for disruptive behaviour disorders (American Psychiatric Association, 1994).

Despite alterations of nomenclature, increasing numbers of researchers have been studying cognitive impairments associated with ADHD. Many have utilised various cognitive tests originally developed by neuropsychologists to evaluate for frontal lobe impairments from stroke, schizophrenia, or traumatic brain injury. These measures, such as the Wisconsin Card Sort (Heaton, 1981), the Rey–Osterreith (Waber & Holmes, 1985), the Tower of Hanoi/London (Shallice, 1982), and others, had been identified in the neuropsychological literature as “tests of executive function (EF)” because they were utilised to assess important cognitive management functions impaired in patients with schizophrenia or traumatic brain injuries, particularly injuries of the prefrontal cortex where the brain’s executive system was assumed to be isolated.

As increasing numbers of studies reported that children and adults with ADHD tend to perform more poorly than normal controls on these purported measures of executive function, some researchers began to describe ADHD as a disorder of executive function. In 1999 Castellanos noted that ADHD is “... not merely a deficit of attention, an excess of locomotor activity or their simple conjunction ...” (p. 179). He observed that “the unifying abstraction that best encompasses the faculties principally affected in ADHD has been termed executive function, which is an evolving concept ... there is now impressive empirical support for its importance in ADHD” (Castellanos, 1999, p. 179).

Although the definition of executive function is still evolving, most researchers agree that the term should be used to refer to brain circuits that prioritise, integrate, and regulate other cognitive functions. Executive functions, then, manage the brain’s cognitive functions; they provide the mechanism for “self-regulation” (Vohs & Baumeister, 2004).

One metaphor to describe executive function is the conductor of the symphony (Brown, 2000, 2005). Regardless of how well the musicians in a symphony orchestra

may play their instruments, they are not likely to produce very good symphonic music if they do not have a conductor to select what piece is to be played, to start their playing together, to keep them on time, to modulate the pace and volume of each section, and to introduce or fade out various instruments at appropriate times. Although each musician may play his or her instrument skilfully, the subtle, dynamic, integrated functioning of the orchestra depends crucially upon the coordinating and managing functions of the conductor.

In a similar way the brain's complex functioning requires and has dynamic integrated management of its component networks. All neural networks are not created equal; some networks manage other networks. Certain neural networks—some in the prefrontal cortex, some in the limbic region, and others in the cerebellum—serve to coordinate and integrate cognitive functions of the brain much as the conductor manages the symphony orchestra (Brown, 2005).

Efforts to assess these executive functions with neuropsychological “tests of executive function” have produced mixed results. Willcutt, Doyle, Nigg, Faraone, and Pennington (2005) recently provided a meta-analysis of 83 studies that administered executive function measures such as the Stop-Signal Task, Porteus Mazes, Tower of Hanoi, and the Wisconsin Card Sorting Task, to groups of children and adolescents with ($N = 3,374$) and without ($N = 2,969$) ADHD. Their analysis indicated that groups with ADHD exhibited significant impairment on neuropsychological measures of response inhibition, vigilance, working memory, and planning. Effect sizes from meta-analytic analysis of these studies were generally in the medium range (0.46–0.49). Willcutt's group concluded that while their results “clearly indicate that EF weaknesses are significantly associated with ADHD, they do not support the hypothesis that EF deficits are the single necessary and sufficient cause of ADHD in all individuals with the disorder” (Willcutt et al., 2002, p. 13).

The conclusion of the Willcutt group that executive function impairments are not the “single necessary and sufficient cause of ADHD” is not important to this present article. The aim here is not to ascertain a cause for ADHD, but to describe the nature of the relationship between ADHD and executive function. It is hard to imagine how even much stronger correlations between scores on executive function tests and ADHD diagnosis could establish any single necessary and sufficient cause for ADHD. Correlation, however strong, cannot establish causation.

What is clear from the data on children with ADHD, and from similar data reviewed in Hervey, Epstein, and Curry's (2004) meta-analysis of executive function tests administered to adults with ADHD, is one fact: If executive function impairment is defined as getting very low scores on tests of executive function, many, but not even a majority, of those with ADHD show significant impairment. If neuropsychological tests of executive function are taken as a valid measure of who is impaired in executive functioning, only about 30% of those diagnosed with ADHD appear to have significant executive function impairments.

But this view of the relationship between executive function and ADHD is only one of the two paradigms considered in this article. Barkley (1997) and the present author (Brown, 2000, 2005) have proposed differing versions of an alternative way

to conceptualise the relationship between ADHD and executive function. Both of our models attempt to synthesise an understanding of executive functions as the brain's mechanism for self-regulation. Furthermore, both describe ADHD as a disorder that involves delays or inadequacies in an individual's development of the capacity for executive function.

Neither Barkley's model nor mine was created *de novo*. Each elaborates upon the work of others who have recognised the wide range of cognitive impairments associated with this disorder. Among those who have described this broader conceptualisation are George Still (1902), Virginia Douglas (1988), Martha Denckla (1994), and Bruce Pennington and Sally Ozonoff (1996). All of these authors have noted the wide variety of cognitive impairments associated with ADHD, and both Barkley and the present author have built upon the foundations they established. Indeed, our efforts have been to provide a model for this disorder that moves even further beyond narrow behavioural definitions and toward greater recognition of the complexity of this syndrome as essentially a developmental impairment of the brain's self-regulatory mechanisms.

In 1997, Barkley described his model as trying to build a case "toward a final verdict that ADHD is a developmental disorder of self-regulation" (p. x). Barkley's (1997) model was based not on data from neuropsychological tests of executive function, but on a conceptual framework derived primarily from Jacob Bronowski's work (Bronowski, 1977) on the crucial importance of language in human development. Integrating Bronowski's model with work by neuroscientists Joaquin Fuster (1989), Antonio Damasio (1994) and Patricia Goldman-Rakic (1995), Barkley (1997) argued that ADHD is essentially impairment in the development of executive function, primarily impairment in the development of ability to inhibit. In Barkley's model the ability to inhibit is the primordial executive function upon which other executive functions are developed. The model elaborates on the essential linkages between inhibition and adequate development and functioning of all executive functions, among which he includes verbal working memory, non-verbal working memory, regulation of emotion and motivation, and reconstitution of behaviour.

In discussing assessment of the syndrome, Barkley (1997) emphasised that ADHD impairments are most noticeable in longer term, cross-situational data of an individual's behaviour over longer intervals of time. He noted "... measures taken in clinics or laboratory assessments over relatively brief temporal durations are going to prove less sensitive to the identification of the disorder and its associated cognitive deficits than will measures collected repeatedly over longer time periods ..." (p. 332). Consequently, Barkley suggested that assessment of ADHD impairment is best done by evaluating the individual's performance in the various domains of daily life:

Evaluating how the individual is performing in meeting daily demands, responsibilities, and other academic, social, occupational, or family obligations will be far more sensitive indicators of ADHD than will evaluations of the individual's knowledge about how to do these things. (1997, p. 335)

He argued that:

... the depth, scope, and seriousness of the impairments rendered by ADHD cannot be clinically appreciated immediately ... to appreciate the larger, more important handicap ensuing from this disorder would require observing the individual with ADHD over considerably longer time periods than anyone except parents, long-time friends, teachers, and employers are likely to have experienced. (p 336; Emphasis in original)

My effort to describe the relationship of ADHD to executive function is, in many ways, similar to Barkley's model, but it has a different primary source. Barkley built his model upon the theories of Bronowski, about the central importance of the capacity to inhibit action and to utilise language. My model was derived from intensive clinical interviews with individuals diagnosed with ADHD and with their families, in which I inquired about specifics of the cognitive and behavioural activities in which these children, adolescents, and adults were impaired relative to others of the same age and developmental level. From these clinical interview studies a wide range of items emerged, from which a set of rating scales for ADHD symptoms in children aged 3–12 years, for adolescents, and for adults were developed (by the present author). Data from these scales, which were completed by patients, teachers, and parents, provided the foundation upon which my model of executive functions that are impaired in ADHD was developed (Brown, 1996, 2001).

The model that has emerged from my research includes six clusters of cognitive functions that constitute a way of conceptualising executive functions for all individuals. None of these clusters is a unitary variable such as height, weight, or blood pressure. Each cluster is more like a basket, containing a variety of related cognitive functions. These clusters are:

- i) *Activation*: Organising, prioritising and activating to work.
- ii) *Focus*: Focusing, sustaining, and shifting attention to tasks.
- iii) *Effort*: Regulating alertness, sustaining effort, and processing speed.
- iv) *Emotion*: Managing frustration and regulating emotions.
- v) *Memory*: Utilising working memory and accessing recall.
- vi) *Action*: Monitoring and self-regulating action.

Each of these clusters is seen as functions operating in rapidly shifting interactive dynamics, usually quite unconsciously, to do a wide variety of daily tasks where the individual must regulate the self using attention and memory to guide action rather than being micro-managed by someone else (Brown, 2001, 2005).

Another primary emphasis of my model is the situational variability of the impairments of ADHD. Clinical studies conducted by the present author have indicated that all individuals with ADHD seem to have some specific domains of activity in which they have no difficulty in performing these various functions that are, for them, so impaired in virtually every other area of life. Often this is described by ADHD patients as simply a function of the level of their personal interest in the specific activity. This situational variability of the symptoms can be viewed as symptoms of the evidence that the impairments of the brain involved in ADHD are not with these fundamental cognitive functions themselves, but with the central management networks that turn them on and off. They can be spontaneously activated and

integrated by situational stimuli that, for the given individual, provide sufficient intrinsic satisfaction or threat to stimulate and sustain response. Adaptive problems arise chronically for the day-to-day tasks that do not present sufficiently strong subjective appearance of immediate threat or reward (Brown, 2005).

These functions, which do not operate perfectly at all times for anyone, are critically important for multiple aspects of daily life in all individuals. ADHD is not an all-or-nothing syndrome like pregnancy, where one either is pregnant or is not. It is more like depression. That is, all individuals experience symptoms of low mood from time to time, but only those significantly impaired over longer periods of time are clinically diagnosed as being depressed. ADHD might thus be considered the extreme end of the normal range of impairments in executive function.

Although my model of ADHD is somewhat similar to Barkley's and both of us describe ADHD as essentially a developmental impairment of executive function, there are two important differences. The two primary differences between our models are that Barkley explicitly limits his model to apply only to those whose ADHD is of the combined type, and that Barkley's model gives primacy to behavioural inhibition as the primordial executive function upon which development and functioning of all other executive functions depend.

The present author does not share Barkley's notion that behavioural inhibition is the fundamental executive function upon which development and functioning of all other executive functions depends. Rather, in my view behavioural inhibition is just one of multiple executive functions; and one that is interactive and interdependent with, not primordially controlling, other executive functions. Moreover, my reading of available data leads to the conclusion that for all persons with ADHD, regardless of subtype, impairments of executive functions are the essence of their disorder. Despite these differences, it is my belief that both models are essentially similar in that both posit that executive function impairment is the essence of what constitutes ADHD.

The conflict between these different views of the relationship between executive functions and ADHD, Barkley's, and the present author's on the one hand, and that summarised by Willcutt et al. (2005), on the other, rests upon how executive function is defined. If executive function is conceptualised simply as a function or set of functions that can be accurately measured by existing neuropsychological tests of executive function, then it is clear that executive function impairment is characteristic of only a substantial minority of those diagnosed with ADHD. However, there is good reason to reject this simplistic definition of executive function as what is measured by "tests of EF".

The present author is in agreement with Rabbit (1997) and other researchers (on impairments of executive function among the elderly) who have argued that such tests violate the central assumption of the nature of executive function. Rabbit explained why methods traditionally used by experimental psychology cannot validly be applied to executive functions. The usual scientific approach in research is to isolate and try to measure one variable that reflects one specific process and not others. He argued that "this venerable strategy is entirely inappropriate for analysing

executive function because an essential property of all ‘executive function’ is that, by its very nature, it involves the simultaneous management of a variety of different functional processes” (Rabbitt, 1997, p. 14).

The usual “isolate the variable and test it” approach simply cannot encompass and measure the complex interactive nature of executive functions. Put another way, in seeking a new conductor for a symphony orchestra, one could not adequately evaluate candidates simply by having them rhythmically wave their arms or hum bars of a specific instrument’s part in a section of a particular symphony. The ability to integrate and guide a large group of musicians through the performance of diverse musical pieces simply cannot be assessed with any isolated musical task. One would instead need to evaluate the candidate’s ability to interact dynamically with the whole group of musicians as they play a variety of complex and challenging pieces.

Paul Burgess (1997) elaborated this same argument against trying to assess executive functions with simple tasks. He stated:

Goethe’s famous comment that dissecting a fly and studying its parts will not tell you how it flies could almost have been intended for the neuropsychology of executive function ... executive processing is called into play only when the activities of multiple components of the cognitive architecture must be coordinated ... Thus, if a methodology is used where a task is broken down into its component parts, no deficit will be discovered in dysexecutive patients. (pp. 99–102)

A person’s ability to perform the complex, self-managed tasks of everyday life provides a much better measure of his or her executive functioning than can neuropsychological tests. Shallice and Burgess (1991) demonstrated this in a study where patients with frontal lobe damage were unable to adequately perform everyday errands that required planning and multi-tasking, even though they achieved average or well-above-average scores on traditional neuropsychological tests of language, memory, perception, and “executive functions.” Similar efforts to assess executive functions in more “real life” situations have been reported by Alderman, Burgess, Knight, and Henman (2003), who assessed adults doing tasks in a shopping mall, and by Lawrence et al. (2002), who monitored children as they followed a series of directions during a trip to a zoo. These contrived situations are likely to be more useful than laboratory tests of executive functions, although they lack the flexibility and scope needed to assess adequately the wider range of executive function impairments in real life.

There is no one test that can determine whether a given individual meets DSM-IV diagnostic criteria for ADHD. It is not like a fracture where a physician can look at an X-ray and definitively see that the bone is or is not broken. This is a diagnosis that depends on the judgement of a skilled clinician who knows what ADHD looks like and can use data from multiple aspects of the individual’s daily life over protracted periods of time to differentiate it from other possible causes of impairment.

The task of differentiating ADHD from other disorders, however, is not easy because ADHD is, more often than not, comorbid with other learning or psychiatric disorders. Kessler (2004) reported on the recent replication of the U.S. National Comorbidity Survey, which found that an adult with ADHD has more than six times

the likelihood of having at least one other psychiatric disorder at some time in life. Furthermore, the MTA Cooperative Group (1999) study of 579 children with ADHD found that more than 70% of these 7–9 year olds met diagnostic criteria for at least one other psychiatric disorder within the year preceding enrolment in that study. And this high percentage from the MTA Group Study does not even include diagnoses for specific learning disorders such as have been reported as present in approximately 50% of children diagnosed with ADHD.

This extraordinarily high incidence of overlap between ADHD and other disorders leads to obvious questions: why should ADHD so often overlap with other disorders? And why would an adult with ADHD throughout his lifetime have six times the likelihood of another psychiatric disorder? In 2002 Sergeant and colleagues published an article asking “How Specific Is a Deficit of Executive Functioning for Attention-Deficit/Hyperactivity Disorder?” They noted that whereas children, adolescents, and adults with ADHD had been shown in many studies to have performance deficiencies on some executive function tasks/tests, similar impairments had also been shown in individuals with other disorders—for example, Oppositional Defiant Disorder, Conduct Disorder, Tourette’s syndrome, learning disorders, and high-functioning autism. The article concluded: “executive function specificity for ADHD remains to be established” (Sergeant, Guerts, & Oosterlaan, 2002, p. 24).

The present author has argued that impairments of executive function are not likely ever to be established as specific to ADHD because most other psychiatric disorders involve both executive function impairments and additional dysfunctions of more specific cognitive systems. Thus, an individual with a reading disorder has impairments of executive functions such as working memory as well as specific problems in aspects of the brain involved in decoding and understanding words. A person with Asperger’s disorder not only has impairments of executive functions involved in shifting focus, managing emotions, and monitoring action, but also has more specific disruptions in aspects of the brain that are essential for noticing and monitoring emotional communications of others (Brown, 2005).

In fact, it does not make much sense to think of such combinations of impairments, some of which involve executive functions, as chance occurrences of separate disorders. The situation is not like having a sprained ankle and influenza at the same time. Rather, impairments of executive function might be compared with disruptions of the operating system of a computer that interferes in various ways with running a wide range of software (Brown, 2005).

It should be noted that the impairments of executive function that constitute ADHD are not the same as general intelligence. Schuck and Crinella (2005) summarised arguments and data that strongly support a distinction between executive function and general intelligence. Contrary to some who seek to equate executive function and IQ, these writers show that correlations between executive function and IQ are, at best, trivial. Their data are consistent with clinical findings that some individuals with extremely high IQ suffer from significant impairments of executive function associated with ADHD (Brown, 2005).

It must be noted, however, that impairments of executive function are not limited to those with ADHD. There are also other ways in which an individual's executive function may become impaired, including for example if an individual suffers a traumatic brain injury in a motor vehicle accident, a person suffers a cerebral vascular accident in specific areas of the brain, or an individual's brain suffers the structural ravages of Alzheimer's dementia. In any of these or other damages of disease or injury to the brain tissue, depending upon location, an individual may suffer from some degree of executive function impairment. The difference between ADHD and these other modes of executive function impairment is that usually an individual with such brain injury or disease has had adequate executive function and then loses it secondary to tissue damage wrought by the trauma or disease. In ADHD, the normal developmental unfolding of executive function has been delayed, most probably by inherited malfunctions of specific neurotransmitter systems (Levy & Hay, 2001).

The two conflicting paradigms currently offered for understanding the relationship of ADHD to executive function involve very different understandings of what executive function is, how it should be measured, and how it is related to ADHD. The view of Willcutt et al. (2005) who see executive function as measurable by traditional neuropsychological "tests of EF" leads to the conclusion that only a relatively small percentage of individuals with ADHD, perhaps about one-third, suffer significant impairments of executive function.

In contrast, Barkley (1997, 2001) and Brown (2000, 2005) claim that all of those with ADHD suffer from significant executive function impairments, and that developmental impairments of these executive functions are the essence of ADHD. We argue that executive function impairments cannot be measured adequately by traditional neuropsychological "tests of EF," and suggest that such impairments can be seen much more clearly and validly in assessments of how individuals perform over time in a wide variety of daily tasks where they must manage themselves.

Differences between these two conflicting paradigms for understanding ADHD might be compared with controversy pending in contemporary Physics. Robert Laughlin, Nobel prize winner in Physics, has argued against the reductionistic view held by many who work in his field. In this era of major technological developments that facilitate microanalysis of subatomic structures and processes, Laughlin (2005) claims there is a need to end "reductionism" as the exclusive way to understanding natural phenomena. By this he means the end of the belief that things will necessarily be clarified when they are divided into smaller and smaller component parts. Laughlin described how phenomena such as the latticing of molecules of water to form ice and the movements of air currents to shape weather patterns involve emergent functions that are not predictable by microscopic analysis of smaller components. He wrote that:

... primitive organizational phenomena such as weather have something of lasting importance to tell us about more complex ones, including ourselves: their primitiveness enables us to demonstrate with certainty that they are ruled by microscopic laws, but also, paradoxically, that some of their more sophisticated aspects are insensitive to

details of those laws. We are able to prove in these simple cases that the organization can acquire meaning and life of its own and begin to transcend the parts from which is made.

What physical science thus has to tell us is that the whole, being more than the sum of its parts, is not merely a concept, but a physical phenomenon. Nature is regulated not only by a microscopic rule base, but by powerful and general principles of organization. Some of these principles are known, but the vast majority are not. (Laughlin, 2005, p. xiv)

Laughlin (2005) argues that many complex physical phenomena can be understood not by analysis of their micro-components, but only as a new level of organisation emergent from complex interaction of multiple components. This view can be compared with the growing edge of modern neuroscience as researchers explore more adequate ways to conceptualise the complexity of human brain function.

Joaquin Fuster (2003) has argued that much of contemporary neuroscience is too reductionistic in analysis of micro-units of brain functioning and suggests that such research “drifts toward the fragmentation of systems and mechanisms” (p. vii). While he proposes a new paradigm that requires a Copernican shift in the way we construe how the cognitive code is represented and processed by the brain, and recognises that there are some modules of the brain that are distinct and very specialised in dealing with myriad forms of sensation and function, he also claims that:

... those areas and modules simply constitute the lower stages of neural processing hierarchies *toward* cognition. The cognitive functions of perceiving, remembering, recognizing, reasoning, and understanding, as well as language, rest on vast territories of cortex that include, but certainly extend beyond those specialized areas and modules. (Fuster, 2003, p. 6)

Fuster’s critique seems especially suited to understanding those most complex cognitive functions that we are describing as executive functions. He notes that the complex range of cognitive activity known as “attention” plays a critical role in multiple overlapping cognitive operations.

Perception is part of the acquisition and retrieval of memory; memory stores information acquired by perception; language and memory depend on each other; language and logical reasoning are special forms of cognitive action; attention serves all the other cognitive functions. (Fuster, 2003, p. 16)

The work of Laughlin and Fuster provides a context for evaluating the contrasting models of executive function in relation to ADHD described in this article. The model that describes executive function as “what neuropsychological ‘tests of EF’ measure” appears to be an overly reductionistic view of some of the brain’s most complex operations.

The alternative model proposed by Barkley and myself is far from fully adequate, and much work needs to be done to refine and assess its usefulness. However, it seems to offer a useful beginning for conceptualising the complex, self-management functions of the mind that are developmentally impaired in individuals with ADHD. Some might object that such a broadly conceptualised phenotype severely compromises scientific efforts to seek genotypes or endophenotypes underlying ADHD. It

does, but this more complex and “messy” model of ADHD as developmentally impaired executive function may bear a closer resemblance to the elegant and complex “messiness” of the brain’s higher operations. As Nobel laureate Gerald Edelman (1992) observed:

The untangling of the complexity has barely begun and the present effort at synthesis will undoubtedly seem paltry when it is over. But even at its early stages, the whole business of the matter of the mind requires a global view if we are going to get anywhere. (p. 149)

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