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Attention and Other Constructs: Evolution or Revolution?

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This article provides a review of the construct of attention from a non-traditional standpoint. Attention is conceptualized by focusing on the categorical concept of the diagnosis of attention-deficit hyperactivity disorder, large-scale brain network models of functional neuroanatomy, and implications for understanding lateralized hemispheric brain organization. Cortical systems are multifunctional, with certain degrees of specialization, but no cortical region or network supports only one, specific, isolated cognitive process, such as attention. Future implications for clinical practice must focus on connectivity patterns rather than the idea of "domains" or "constructs" when considering attention and other cognitive processes. This has significant implications for the future of neuropsychological assessment and intervention.

Key words: *ADHD, assessment, attention, connectivity patterns, large-scale brain networks*

INTRODUCTION

A number of practicing clinical neuropsychologists were invited to participate in this series of articles on the *construct* of attention. As it turned out, five clinicians participated, and all together, including secondary authors, many of these contributors work in clinical, academic, and research settings. So even though there are a small handful of articles in this volume, the experiential background of the authors represents a solid sampling of viewpoints from the field. Most editors of this type of project would typically summarize the manuscripts, comment on similarities and differences in viewpoints, provide integration, and perhaps provide a few ideas of his/her own. Each contributor to this volume has a specific "niche," based on a neuroscientific frame of reference, which therefore generated unique points of view. Just about every article concluded that traditional constructs of attention are outmoded, although we continue to assess attention from a clinical viewpoint that leads to limited practical applicability. In fact, every manuscript either stated, or implied, that relevant features of attention are not even assessed in current neuropsychological assessment practice. This review focuses on several specific issues and admittedly deviates from "tradition" by extending beyond the typical summary and integration of a typical editorial overview. In fact, two additional coauthors accepted invitations to contribute to this manuscript to take this review a step further, so this "summary" actually can be considered a "standalone" article that "rests on the shoulders" of the previous manuscripts. It literally "picks up" where the other articles "left off." This manuscript focuses on three areas—namely, the categorical concept of the diagnosis of attention-deficit hyperactivity disorder (ADHD), large-scale brain network models of functional neuroanatomy, and implications for understanding lateralized

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hemispheric brain organization. If the clinical field is to remain viable, these areas are absolutely critical for understanding the construct of attention and for incorporating this information into current and future neuropsychological evaluation. Along the way, we question the traditional, yet arbitrary concepts of ''domains'' or ''constructs.'' And all authors agreed this approach was justified, at least with respect to significantly adjusting our ideas about attention as a construct. This approach places into practice a quote from Thomas Jefferson: ''A little rebellion now and then is a good thing'' (Thomas Jefferson to James Madison, Paris, January 30, 1787).

ATTENTION-DEFICIT HYPERACTIVITY DISORDER

It seems as though many times when the word ''attention'' is mentioned in *clinical* neuropsychology, the discussion inevitably turns to ADHD as defined by the *Diagnostic and Statistical Manual of Mental Disorders*-Fifth Edition (DSM-5; American Psychological Association, 2013). Why this occurs, when we try to understand ''attention'' as a construct from an objective point of view, is difficult to explain. And on this point, two directly related issues warrant discussion. First, ADHD is a *behaviorally defined diagnosis* as it is characterized in the DSM system. And in this regard, we completely agree with Carmichael and colleagues' (this issue) bold statement that from a *neuropsychological* perspective, ADHD does not exist. There are absolutely no broad-based neuropsychological test batteries that can ever lead to that diagnosis nor is there any ''litmus test'' for the disorder called ADHD (Koziol, Budding, & Chidekel, 2013; Koziol & Stevens, 2012). However, the fact of the matter is that from the behaviorally defined DSM system, ADHD does exist. It has remained alive and well ever since this categorical diagnosis was introduced into the DSM. This matter has a long history of controversy, and without endorsing, defending, or indicting anyone's specific point of view, clinical neuropsychologists are compelled to agree with the proposal that history, observation, and behavioral rating scale data are the primary methods for diagnosing ADHD (Barkley, 2006). In fact, we go a step beyond that viewpoint in stating that these simple behavioral methodologies are the *only justifiable* means for making that diagnosis. This conclusion is based on one simple fact: *If a clinician is bound by the DSM system*, which by definition is a behaviorally defined categorical and observational methodology, the only way to diagnose the disorder is to rigidly adhere to the ''rules'' of the DSM-5. The exact same conclusion applies to the International Classification of Diseases system (World Health Organization, 1992).

Another ''fact'' of the matter is that *neuropsychology does not have an organized, universally agreed-upon diagnostic system.* Clinical methodologies in neuropsychology identify *symptoms.* In our opinion, there is absolutely no reason to literally ''force'' neuropsychological methodologies into a system that was never designed or intended to accommodate clinical neuropsychology. The DSM-5 and neuropsychological tests, methods, and procedures were never intended to ''merge.'' In fact, there is absolutely no available data that even suggest neuropsychology and the DSM were ever meant to complement one another. There are numerous studies that describe how well certain broad-based neuropsychological test batteries, or even single tests, *correlate* with a diagnosis of ADHD. However, correlation basically informs us of the percentage of time any given test or batteries of procedures are seen in populations with a behaviorally defined DSM diagnosis of ADHD. This is not the same as *diagnosing* the disorder with neuropsychological methodologies. Instead, neuropsychological test results identify *symptoms* and provide descriptive nomenclature. Given that behaviorally defined ADHD populations are heterogeneous, neuropsychological evaluations are useful in identifying heterogeneous symptoms that might/might not warrant treatment. The diagnostic use of behavior observation is *not* a threat to neuropsychology because it is also well documented that the results of neuropsychological evaluation can play a significant role in the functional outcomes of children diagnosed with ADHD (Pritchard, Nigro, Jacobson, & Mahone, 2012). It is not a matter of which methodology or approach is ''better.'' Both ways of approaching the study of attention provide completely different types of information and can be used synergistically. In aggregate, behavioral assessment and neuropsychological evaluation generate an entirely new ''product.'' This leads to powerful diagnostic and symptom identification data that should be used constructively. However, within the current state of development of the field of clinical neuropsychology, it is absolutely critical for each and every practitioner to recognize the distinct differences between behaviorally defined identification and the descriptive neuropsychological nomenclature used to identify cognitive and behavioral symptoms identified in completely different ways. Every practitioner needs to know how to be proficient in the application of both DSM-5 and neuropsychological approaches to be effective in diagnosis, symptom identification, and treatment. It is only in this way that the field can move forward and develop further with respect to understanding the difference between ADHD and the artificial construct of attention. In fact, we believe arguing over which approach is more effective is not only distracting, but potentially damaging to the field of neuropsychology. The point cannot be overemphasized that these two perspectives provide unique, separate "data sets." For example, automobiles and airplanes are alike because both are articles of transportation. Both provide different but critical functions. A car cannot transport you over an ocean; a jetliner is unable to transport you to a local family get-together. In fact, for many "trips," both modes of transportation are inevitably necessary. There is absolutely nothing wrong with acknowledging that DSM-5 diagnosis and neuropsychological assessment can coexist. The synergy provides a very useful product and offers unique contributions often of critical significance in guiding treatment.

We are also well aware of the research domain criteria (RDoC; Sanislow et al., 2010) project, which the National Institute of Mental Health launched in 2009. The RDoC project significantly contributes to our understanding of both the etiology of clinical disorders and symptom identification. The RDoC project has not only led to more effective ways of treating people, but it also assists in preventing certain neurodevelopmental disorders; it encourages multiple methodologies and generates a completely new, and critically necessary, understanding of how behavior is organized within the brain. The RDoC project addresses how and why disorders are generated, why comorbidities occur, and how to proactively use this information to enhance people's lives. We also understand the RDoC structure is arguably critical of the DSM-5 system because DSM-5 diagnoses fail to align with neuroscientific findings. We endorse this new methodology because we recognize its inherent value. Nevertheless, even a brief summary of this approach is well beyond the scope of this article (for comprehensive reviews, see Casey, Oliveri, & Insel, 2014; Cuthbert & Insel, 2010; Insel et al., 2010; Sanislow et al., 2010; Voeller, 2004; Whelan et al., 2012).

The second issue in this section concerns the failure to identify a "global" attention system or network. This is also true for the diagnosis of ADHD. For instance, if a diagnosis such as ADHD existed, one would expect to find a specific brain system, or network, as an underpinning for that disorder. Recent meta-analytic data demonstrate the most replicated anomalies in ADHD are characterized by smaller volumes in the dorsolateral prefrontal cortex, certain regions of the basal ganglia such as the caudate nucleus of the striatum and the globus pallidus, the corpus callosum, the cerebellum, and within certain white-matter tracts projecting from and to these identified brain regions (Durston, Belle, & Zeeuw, 2010; Seidman, Valera, & Makris, 2005). On the one hand, this speaks toward the inability to demonstrate any ADHD "network" common to the disorder; on the other hand, the picture that emerges is consistent with the heterogeneity of presentations characteristic of this behaviorally defined population as a group. Similarly, this is consistent with clinical neuropsychology's inability to reliably differentiate anyone diagnosed with ADHD across any of its *Diagnostic and Statistical Manual of Mental Disorders*-Fourth Edition, Text Revision (DSM-IV-TR; American Psychiatric Association, 2000) defined subtypes (Doyle, Biederman, Seidman, Weber, & Faraone, 2000; Hinshaw, Carte, Sami, Treuting, & Zupan, 2002; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). It is important to note that the DSM-5 remains in transition from the DSM-IV-TR, and meaningful studies that might demonstrate any possible differences were not available at the time of this writing; however, given the categorical nature of the DSM system, which again is not based upon functional neuroanatomy and/or neuropsychological descriptive symptom validation, few, if any, differences might be expected. Furthermore, Castellanos and Proal (2012) hypothesized how ADHD might be explained within the context of identified large-scale brain systems, and Cortese and colleagues (2012) described how the varied presentations of ADHD can be understood within the context of these systems. However, while focusing on ADHD, others expanded upon this proposal by considering how ADHD might be used as an "anchor point" serving as a model of brain–behavior relationships (Koziol, Budding, & Chidekel, 2013).

In addition, it is also notable that neuropsychology has no readily agreed-upon definition of attention and that neuroimaging studies have never identified a single or unitary brain network for attention. Performances on neuropsychological test batteries do not suggest a unitary cognitive profile that supports a unitary construct of attention. The "Mirsky model" of attention, proposed approximately 25 years ago, featured distinct elements of attention that operated as a well-orchestrated unit (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991). However, this "cognitive network" model was based on a hypothetical, theoretical neuroanatomy derived from animal and human "lesion" studies. Koziol, Joyce, and Wurglitz (2014) updated this model by adapting Mirsky's components of attention according to currently available neuroscientific findings concerning large-scale brain systems. This updated paradigm resulted in the identification of multiple neuroanatomical substrates, which differed from the initial putative proposal, neither of which has been systematically investigated. Although the "Mirsky model" allowed for a systematic examination of attention-related functions, it was never adapted as the "standard" in practical clinical assessment. Consistent with conclusions that emerge from reviews in previous articles in this volume, all of this makes us question whether or not we have been asking ourselves the proper questions about understanding attention as even a multiple-component process. Just as the DSM system does not align well with neuroscientific findings, neuropsychological test results do not align very well with neuroscientific data either. Simply put, both DSM diagnoses and arbitrarily defined neuropsychological constructs are characterized by a huge gap against the background of neuroscience. In this way, the seemingly trivial saying, "*People who live in glass houses shouldn't throw stones*" is quite applicable here. The field of clinical neuropsychology has a bit of "house cleaning" to do.

CONSTRUCTS WITHIN THE CONTEXT OF LARGE-SCALE BRAIN SYSTEMS

Joyce and Hrin (this issue) reviewed the concept of large-scale brain systems as originally identified by Yeo and colleagues (2011). They also cited a paper that described how large-scale brain systems can be applied to updating a systematic neuropsychological model of attention. This application reinterpreted the functional neuroanatomic underpinnings of attention as initially proposed by Mirsky (Koziol, Joyce et al., 2014). However, perhaps the most significant feature of the seven-network brain system, reliably identified over a large sample size, was the conspicuous absence on any single system or network related to any *overall* construct of attention. It has long been known that any simple construct of attention does not do justice to the numerous "elements" of attention that are necessary for the performance of any given task, and multiple theoretical models have been proposed (Mesulam, 1985; Mirsky et al., 1991; Posner & Petersen, 1990; Pribram & McGuinness, 1975). However, none of these theoretical models have ever been associated or correlated with a predictable functional neuroanatomic substrate. In fact, current functional neuroimaging data of brain networks and functions call into question the very concept of artificial or arbitrarily defined categorical "domains" or their presumed subsets. Perhaps the only domain that can arguably be identified is nested within the sensorimotor network (SMN), but this network is characterized by numerous subsets of brain systems. Similarly, sensorimotor examinations are typically not included routinely in neuropsychological evaluations. Although textbooks identify this domain as "distinctly useful" in neuropsychological evaluation, motor and sensory-perceptual data are often minimized, examined in a cursory way, or even entirely omitted (Baron, 2004; Lezak, Howieson, Bigler, & Tranel, 2012).

In contrast to the traditional view that "cognition" is separate from motor functioning, we believe that sensorimotor functioning is critical. There is no duality of function between cognition and motor behavior; everyone was literally born to live, or interact, within a dynamically changing environment (Cisek & Kalaska, 2010; Koziol & Lutz, 2013). All knowledge can even be understood to be "grounded" in sensorimotor anticipation (Pezzulo, 2011). This generates further question as to whether "domains" as originally proposed on the basis of "face validity" really exist. Perhaps we should replace the notion of domains with the concept of "embodied cognition" (Koziol et al., 2012). The overarching general domain concept might be reduced to an artificially derived methodology for organizing the interpretation of test data that have little correspondence with neuroanatomic substrates. We also realize that to our knowledge, the domain concept has never been formally challenged and this conclusion is generated on the basis of recently identified functional brain systems and their constantly changing patterns of activation that are always task-dependent (Cole, Bassett, Power, Braver, & Petersen, 2014; Cole et al., 2013).

We are definitely cognizant that violating tradition puts us at risk for being considered "rogue." However, the current "interim solutions" of neuroscience do not align with arbitrarily defined and taught constructs. There are a number of concepts lacking neuroscientific support. These models include, for example, those models denoting aspects of attention; those that focus on blatant, explicit learning and memory functions, without considering implicit learning; the "umbrella" term of "executive functions" and its conceptually, hypothetically based subsystems; and the seemingly unmovable conclusion that "cognitive" and "emotional functioning" are compartmentalized. But either neuropsychology's clinical methodologies are incomplete or neuroscientific findings that have been consistently replicated and further refined in recent years are incorrect and misleading. There is an obvious dichotomy in these views, and by analogy or example, the brain is not at all organized along the almost religiously adhered-to principle of "verbal versus nonverbal" hemispheric organization.

Networks of attention are organized in a completely different way in comparison with how neuropsychology has tried to identify attention and/or its presumed subsystems such as sustained attention, auditory attention, visual attention, and the all-too-frequently-used term of "shifting" attention, etc. Each and every one of these constructs can only be defined operationally and never apart from the "tests" that measure them (Wasserman & Wasserman, 2013). Unfortunately, apart from those specific contexts, none of these constructs are related to any specific neuroanatomic substrate.

The structure and function of the seven-network parceling of the cerebral cortex was described previously within several volumes of this journal (see Joyce & Hrin, this issue; Koziol, Barker, Joyce, & Hrin, 2014; Koziol, Joyce, et al., 2014; Koziol & Stevens, 2012). While these same networks can be identified in children, adolescents, and adults with resting-state neuroimaging technologies, Menon (2010) noted a close correspondence of these networks with functional patterns of activity. Cole and colleagues (2014) further investigated the relationship between resting-state network identification and the brain networks recruited across 64 separate tasks. They found that the most frequent functional connectivity strengths across all tasks closely matched the same strengths observed at rest. This implies a truly "intrinsic," very basic and standard architecture of functional brain organization, further validating and refining the findings of Menon and the consistent replications reported by Yeo et al. (2011). In addition, a small, but highly consistent set of task-related changes, common across all tasks, identified a "task-general" network architecture that distinguished resting states from task states. In other words, regardless of task, a unique, small, but consistent pattern of changes was observed in the same way on every task. Therefore, there is not only a specific seven-network architecture that is identified both at rest and during task performance, but there is also an additional "task-general" network activated by all tasks. Furthermore, there is a recruitment of brain network activation that is task network-specific. Therefore, there is an extremely strong relationship or correspondence between the brain's resting-state functional connectivity and task-evoked functional connectivity, with the additional identification of a task-general network only observed upon task activation, regardless of task. In other words, it is literally impossible to employ any neuropsychological tests that are characterized by multiple-component test structure and expect to identify any artificial construct that recruits a unique pattern of brain network activity. This explains why any construct operationally defined by a specific test performance can only be identified by that particular task itself. Brain–behavior relationships are simply not identified by artificially derived constructs such as "domains," while even slight changes in task presentations will evoke different patterns of network activation. This actually calls into question any neuropsychological test constructs that are statistically derived. This provides a strong argument against atheoretical test construction and then identifying parameters of behavior according to face validity. And it speaks to endorsing the use of the exact same neuropsychological tests and methodologies that have been successfully used as "probes" in experimental studies for the understanding of brain–behavior relationships. Furthermore, these types of data should never be "forced" into the statistically derived normal distribution of a "bell-shaped" curve when, in fact, many of these experimental findings are "skewed" and represent pathognomonic findings!

For example, there are several commercially available neuropsychological continuous performance tests (CPTs). They are all constructed in different ways and do not correlate very well with each other (Riccio, Reynolds, & Lowe, 2001). Some are based on "visual" stimulus presentations; some are based on both auditory and visual modalities. The frequencies of stimulus "targets" are different for each test. These stimuli are often presented at different rates for different tests, and often times with changing rates of stimulus presentations within the task. According to current brain network data, there is no reason to expect these "tests" to correlate strongly with each other because the changing task characteristics should elicit certain similar but other distinct brain networks based on task demands. So what exactly is "sustained attention"? The question almost inevitably boils down to which CPT is "better" as related to a DSM-5-defined diagnosis of ADHD! Again, if neither the DSM-5 nor neuropsychological tests "map" very well onto neuroanatomic brain substrates, perhaps we have been asking the wrong question all along. In fact, Wasserman and Wasserman (this issue) and Hale and Fitzer (this issue) seem to question the very construct on a similar foundational basis. Fan and Posner (2004) developed a three-component model of attention consisting of alerting, orienting functions, and the executive control of attention. On the one hand, this was an attractive proposal, and currently, it is not surprising to observe the significant "network overlap" of that system with aspects of recently identified reliable brain systems. On the other hand, the original proposal requires updating, and the Attention Network Test the researchers developed requires investigation within the context of what is known about large-scale brain systems. The construct of inhibition, inherent in attention, has also been questioned and examined (see Carmichael et al., this issue; Hale & Fitzer, this issue). However, there is no evidence of a unitary construct of "inhibition" (Rush, Barch, & Braver, 2006). Different inhibitory tasks recruit different brain networks, identified by functional magnetic resonance imaging, so that this construct is also task-dependent (Simmonds, Pekar, & Mostofsky, 2008). Many tasks of inhibition involve complicated stimulus detection and associated processes, and they recruit so many brain networks that they are almost impossible to disentangle (Criaud & Boulinguez, 2013). Simply put, different tasks "map" distinct and/or overlapping brain networks (Kipp, 2005; Stevens, Kiehl, Pearlson, & Calhoun, 2007). "Inhibition" networks also change over time, which clearly has implications for pediatric development. Barkley reported that inhibitory control is difficult to measure in adult populations (Barkley, 2006, Kipp, 2005). CPT performance can be useful in identifying inhibitory control in school-aged children with ADHD, but the inhibition of saccades (oculomotor inhibition) is the most sensitive index of inhibitory control in adults with ADHD (Roberts, Fillmore, & Milich, 2011). However, even within the same affected adult, other types of "stopping" or motor inhibition, even on complex tasks, can be well localized on a stop-signal task and are generalizable to ecologically valid scenarios (Wessel & Aron, 2014). This type of dissociation helps explain why the impulsivity of ADHD might be observed in certain situations that can involve organization and planning, yet it does not disturb the type of inhibition required for "stopping" in complex yet automatic tasks such as driving a car. Many "readymade" test batteries for evaluating children and adults have several indexes called "inhibition." However, within the context we established, why not ask the question, "What do these indexes measure and how are they of clinical diagnostic significance?" If these questions cannot be answered, we should ask ourselves, "What are we measuring?" If we blindly interpret these indexes, what assumptions are we making? Is this not the same as using the test or index according to simple "face validity" and using these "tools" to identify a symptom or make a diagnosis without knowing anything about the relevant brain-related substrates? Does this approach not violate the fundamental definition of neuropsychology? Utilizing this type of approach would be universally unacceptable in any other health-related profession. The relevant issues have become complicated in this field. It is time to pause, stop, and start asking ourselves "new" sets of questions to find "new" solutions.

ATTENTION AND THE LATERALIZED HEMISPHERIC ORGANIZATION OF BEHAVIOR

A recent revision of the "Mirsky model" demonstrated how different elements or components of attention can be understood within the context of large-scale brain systems (Koziol, Wurglitz et al., 2014). Furthermore, "revisiting" this model illustrated how it remains relevant in current neuropsychological assessment. However, additional components of attention and how they might be measured are also critical to understand for clinical neuropsychology to unite with neuroscientific findings. In this section, we describe how other features of attention are organized within the brain according to principles of hemispheric lateralization. But this requires abolishing the principle of hemispheric organization based on the "verbal–nonverbal" dichotomy, while simultaneously acquiring a deeper understanding of the language "domain" (serving as just one example) and other functions, such as attention. This also further illustrates why all "domains" are artificial, arbitrary constructs. These just might be "tough pills to swallow"!

If the traditional left-versus-right-hemisphere dichotomy is simply reduced to a verbal–nonverbal principle of brain organization, then we are forced to ignore the well-documented neurobiologic consistency of the vertebrate brain. And if we accept this consistency over 500 million years of phylogeny, we are compelled to "ask questions" about the "fixed" assignment viewpoint that language resides within the left hemisphere, which emphasizes the uniqueness of the human brain because of specialized linguistic systems. It is impossible to have it both ways. Inherent in any health-related field is the concept of asking critical questions that lead to a diagnosis in order to treat a patient. So we are offering a way to diagnose and treat certain problematic issues within the field of clinical neuropsychology in order to treat them! Therefore, what other way of lateralizing hemispheric brain function might help diagnose and treat some of neuropsychology's problems?

In our opinion, the novelty-routinization principle of vertebrate brain organization is the critical game changer (Goldberg & Costa, 1981; MacNeilage, Rogers, & Vallortigara, 2009), and we are at a total loss in trying to explain why clinical neuropsychology has never "paid attention" to it! This overlooked principle of lateralized brain functioning has been known for quite some time and is the underpinning for a deeper understanding of distributed brain functions and large-scale brain networks and systems. The left hemisphere is specialized for the control and execution of well-established patterns of behavior under ordinary, familiar circumstances; the right hemisphere is specialized for detecting and responding to novel, unfamiliar, or unexpected stimuli. Dynamically changing brain interactions are inherent in this lateralization principle because every vertebrate survives by continuously interacting within a changing environment. The left hemisphere exploits predictable, routine features of the world by responding in an "automatic" way. The underpinning of automatic behavior always involves a predictable "sequence" of motor behavior or "action." Few situations are completely predictable, and many circumstances are completely novel. This requires novelty detection and the modification of a "known" behavioral sequence or the development of a "new" adaptive response (Toates, 2006). The fundamental "job" of any brain is to learn behaviors that are adaptive, and the more frequently these learned responses are "used," executed, or "practiced," the more automatic they become (Ito, 2008). This allows for biologically economic functioning and conserving precious biologic resources; automatic behaviors are adaptive, even elegant, and almost effortless (Bruya, 2010; Saling & Phillips, 2007). Developing and learning completely new behaviors is effortful; it requires energy expenditure and is typically "slow." That said, it would be expected that behaviors are organized along a hierarchy and this assists in understanding certain individual differences; what is "new" for one person might be "routine" for another. This is particularly important for understanding pediatric development; knowledge and "action" are "grounded" in interaction with the environment and are gradually acquired during a protracted period of time (Pezzulo, 2011). This pattern of hemispheric organization is also biologically consistent across vertebrate phylogeny (see Podell, Lovell, & Goldberg, 2001, for a comprehensive review).

If this principle is "true," there must be an identifiable functional neuroanatomy that supports this system. Goldberg and Costa (1981) were arguably the first, though limited by the technologies available to them, to identify this anatomy, albeit in a more global "brain region" way. Recent studies of large-scale brain systems and functional specialization refine the initially proposed anatomic substrate and support predictions that might be made from our knowledge about brain networks.

The frontoparietal network (FPN) is highly specialized in both hemispheres (Wang, Buckner, & Liu, 2014). The FPN and the default mode network (DMN) are the most specialized within the left hemisphere, while the visual network (VN), the ventral attention network (VAN), and the SMN are the least specialized. This supports the fact that the cognitive control of novel problem solving, recruiting the left-hemisphere FPN, is preferentially connected to the DMN for the effortful cognitive task performance that requires information/knowledge or rules to be held in mind for the *internal* guidance of behavior. This is the left-hemisphere network that is critical for guiding behavior according to the content of what one is thinking about for contextually dependent functioning. And the fact that the VN, VAN, and SMN are the least specialized makes good sense, because automatic or routine behaviors and the operations of the VN/VAN are not particularly relevant for guiding behaviors according to what a person is thinking about. The FPN, VAN, and the dorsal attention network are preferentially and highly specialized within the right hemisphere—what might be termed a global attention system. The right-hemisphere FPN functional specialization profile is the substrate for cognitive selections driven by the *external* environment for context-independent behavior, which is necessary for identifying and orienting to task novelty. FPNs are highly specialized in both hemispheres while, collectively, they rapidly and flexibly recruit and update whatever brain systems are necessary for any particular context or situation (Cole et al., 2013). Importantly, as reported by Wang and colleagues (2014), *the cerebellum parallels this cerebral hemispheric functional specialization pattern, but in the contralateral cerebellar hemisphere.* This is a critical point because the cerebellum is critical to the automation and ongoing adjustment/adaptation of behaviors (Ito, 1997, 2011; Njiokiktjien, 2010).

Broca's area, a node within the left-hemisphere FPN, is activated when information is expressed through language. There are aspects of the "canonical" left-hemisphere cortical-subcortical linguistic system that can be identified in 8-year-old children and the trajectory of the development of this "subnetwork" can be observed (Broser, Groeschel, Hauser, Lidzba, & Wilke, 2012). However, regions within this subnetwork also participate in the execution of other tasks (Hillert, 2014). And because this system is driven internally, by what one is thinking about, the quality of the linguistic expression might be expected to be literal and personalized, which in fact is the case. While the medial temporal lobe memory system is a "hub" within the DMN, it would be predicted that factual and even personal autobiographical recollection would be concrete and literal, an inherent property of this type of information. However, right-hemisphere networks process many types of linguistic information. This includes the resolution of ambiguity when words have multiple meanings, metaphorical understanding, appreciation of humor, judgment and expression of affective language prosody, as well as the processing of the figurative and pragmatic aspects of language; all of these linguistic properties are driven by external factors independent of personal, internal context. For example, novelty, at least to some degree, is an inherent property of conversational discourse, which includes *external* factors. The left hemisphere processes literal, detailed, routinized, and automatic information; the right hemisphere is specialized for processing closely related words as specific to the external context, appropriate affect, and the semantic integration required for the particular "novel" circumstances for the specific external situation—all of which have been demonstrated clinically and experimentally (Bryan & Hale, 2001). The right hemisphere is clearly not irrelevant to the linguistic system. Therefore, by divesting language of its cardinal role in left-hemispheric specialization and reinvestigating the novelty-routinization principle of hemispheric brain organization, we open the door for incorporating phylogenetic consistency, we rid ourselves of the limitations inherent in any "fixed assignment" processing of any cognitive function or arbitrarily defined domain, we can understand a dynamic instead of a static view of brain organization, we can see how a pattern of hemispheric specialization might be different at changing stages of development, and we can understand how the locus of control shifts from one hemisphere to the other during the course of any "cognitive" and/or skill development. All of these conclusions are supported by our knowledge about the functions of large-scale brain systems. Within this framework, left-hemisphere "specialization" for language is a "specific instance" of the "sequencing" and routinization inherent in left-hemisphere information processing. This principle far surpasses any understanding of the "language domain" that might be achieved through a simplistic left-hemisphere assignment. And this principle, organized within the seven-network parceling (reviewed in numerous previous editions of this journal), is completely consistent with the conclusion that the bilateral FPN region operates as a flexible "hub," constantly updating the pattern of functional connectivity with other brain systems according to specific, and changing, task demands. And we might add that the immediate question that might be raised—"What about the visual-spatial domain?"—can also be easily understood within this same principle. The answer is easily reframed within the context of right-hemisphere brain network organization. In ambiguous, novel situations, the human brain makes decisions that are partially defined by the momentary "geometry" of the immediate environment and change during continuously ongoing activity (Cisek & Pastor-Bernier, 2014).

SUMMARY

This extended summary attempted to integrate aspects of the previous manuscripts of this special issue, and it attempted to dissociate the diagnosis of ADHD from neuropsychological constructs of attention. During the course of this discussion, we questioned all commonly accepted models of attention, as well as more broadly addressed the problems of understanding cognition and behavior according to all traditional and artificial constructs of domains. "Tradition" is simply not consistent with the manner in which behavior is organized within the brain as revealed by current neuroscientific investigations of brain networks. What "holds true" for the organization of attention is similarly true for any other cognitive domain. Simply put, cortical systems are multifunctional, with certain degrees of specialization, but any cortical region or network does not support only one, specific, isolated cognitive process such as attention. The most critical questions concern how brain systems share their resources and how they coordinate their activities to provide the functional integration that is required to complete any individual task. The specific recruitment of any brain system for any "cognitive" process, including attention and even language by our illustration, is determined by its connectivity patterns. It is the kind of interactions with other brain networks that is the variable of interest, and these brain interactions typically involve not only left-hemispheric networks but also right-hemisphere systems, dependent upon the varied, dynamically changing phases of task demands. This represents the most critical feature for understanding any "cognitive domain" and defines the most significant challenge for clinical neuropsychology to meet as the field moves forward.

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