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A Conceptual Model of Child Psychopathology: Implications for Understanding Attention Deficit Hyperactivity Disorder and Treatment Efficacy

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Highlights the desirability of using a theoretical framework for guiding the design and evaluation of therapeutic interventions for children with attention deficit hyperactivity disorder (ADHD). A general conceptual model is introduced and used to evaluate ADHD treatment outcome research. Treatments designed to target the substrate level (pharmacological interventions) result in broad, robust improvement in both core and peripheral areas of functioning. Those targeting hypothesized core features of the disorder (i.e., attention, impulsivity–hyperactivity) produce corresponding improvement in core and peripheral outcome measures with the exception of studies employing cognitive–behavior therapy. Those targeting peripheral features of the disorder effect change only in corresponding peripheral areas of functioning. Implications for clinical practice are discussed, and an alternative conceptual model of ADHD is introduced and compared with existing models.

Over 4 decades of research substantiate the clinical efficacy of behavioral interventions as a primary, complementary, or alternative treatment for children with attention deficit hyperactivity disorder (ADHD). These interventions focus on a wide range of behaviors (e.g., academic performance, compliance or rule following, social skills or peer and parent interactions), are used in diverse settings (e.g., home, school, extracurricular, leisure), and require considerable involvement by others (e.g., mental health professionals, parents, teachers, peers, siblings) to achieve desirable levels of efficacy. The severity, chronicity, and multifaceted nature of behavior problems associated with the disorder demand the breadth and intensity of present-day behavioral interventions.

Despite a growing sophistication in the field, behavioral treatment of ADHD in its most potent form is usually (Gittleman et al., 1980; Gittelman-Klein et al., 1976; Loney, Weissenburger, Woolson, & Lichty, 1979; Pelham et al., 1993) but not always (O'Leary, Pelham, Rosenbaum, & Price, 1976; Rapport, Murphy, & Bailey, 1982; Wolraich, Drummond, Salomon, O'Brie, & Sivage, 1978) judged less potent compared to pharmacological management with stimulants. Recent findings of the National Institute of Mental Health multicenter Multimodal Treatment Study for ADHD (MTA), which compared intensive behavioral treatment, psychostimulant treatment, and combined therapy over a 14-month time period for large numbers of children with ADHD, corroborate the superiority of psychostimulant over behavioral intervention (MTA Group, 1999).

One reason for differences in clinical efficacy between pharmacological and behavioral treatments—assuming similar levels of integrity—concerns the selection of target behaviors and their hypothesized relation with the disorder's central features. This and related conceptual issues relevant to bridging the gap between theory and clinical practice serve as the focus of this article.

A basic conceptual model of ADHD based on extant literature is illustrated in Figure 1 and elucidates the implicit and explicit causal assumptions underlying both behaviorally based and pharmacotherapeutic interventions for children with ADHD. It suggests that biological influences (e.g., genetics, prenatal insults) give rise to individual differences in the functional properties of neurobiological systems (e.g., dopaminergic–noradrenergic neurotransmission) that are etiologically responsible for the core psychological (i.e., cognitive and behavioral) features of ADHD. Secondary and peripheral features of ADHD (e.g., those listed as associated features in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed. [*DSM–IV*]; American Psychiatric Association, 1994) are conceptualized here as causal byproducts of core features. For example, the ac-

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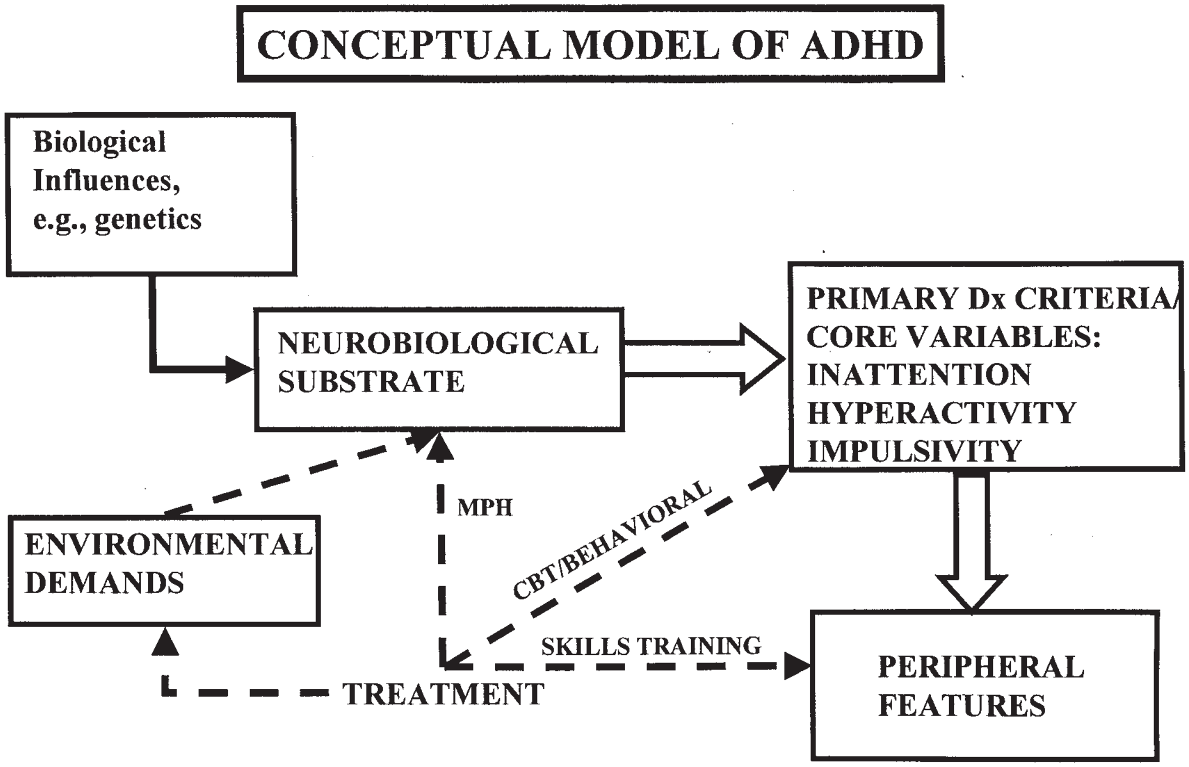

Figure 1. A conceptual model of attention deficit hyperactivity disorder (ADHD) based on extant literature. MPH = methylphenidate. CBT = cognitive–behavior therapy.

ademic underachievement observed in many children with ADHD is presumed to be a causal consequence of broader, more primary features of the disorder, such as chronic inattention to and lack of persistence on classroom tasks. Other peripheral features common to ADHD, such as inadequate social skills and peer relationships, low frustration tolerance, and strained family relationships, are similarly presumed to be due to core behavioral and cognitive influences.

Implications for designing behavioral treatments and hypotheses concerning expected levels of efficacy are readily derived from the model. Interventions aimed at improving core psychological–cognitive features of the disorder should produce the greatest level and breadth of therapeutic change, accepting the caveat that core features are correctly specified as opposed to representing reified symptoms in the *DSM–IV.* This is accomplished either by targeting a core cognitive process such as attention or by designing classroom environments that minimize demands on the hypothesized substrate as illustrated in Figure 1 (for a description of a model classroom, see Rapport, 1998). Those aimed at peripheral behaviors should show limited generalization upward to core features and minimally affect other peripheral features in term of measured treatment effects over and above what would be expected based on overlapping behavior topographies. Exceptions to this hypothesized pattern would be expected when core and peripheral features show extreme overlap with one another with respect to shared underlying processes (e.g., the degree to which attention or impulsivity–hyperactivity correlates with a particular peripheral manifestation in children).

With these considerations in mind, four sets of representative studies targeting variables at different levels (substrate, core, peripheral, environmental) are examined to illustrate the potential usefulness of the conceptual model for understanding differences in therapeutic efficacy among interventions. We initially examine a study that compares pharmacological and behavioral treatment for children with ADHD to determine whether the interventions differentially affect core and peripheral variables as predicted by the model. The second and third sets of reviewed studies target core (i.e., attention or impulsivity–hyperactivity) and peripheral variables (e.g., following rules, classroom deportment), respectively. A single study was located that examined the effects of different learning environments on one of the core features of ADHD.

Effect sizes (ES) were calculated for the various dependent variables used in studies to facilitate comparisons both within and across data sets. For the two pre- and postcomparison (treated vs. control group) study designs (see cognitive–behavior therapy [CBT] interventions targeting the core feature impulsivity), insufficient data were reported to calculate traditional ESs and compounded by differing rates of attrition between groups at postassessment intervals (i.e., pooled standard deviations could not be calculated). For these studies, an ES ratio was calculated using the following method: The postassessment mean was subtracted from the preassessment mean and divided by the pretreatment standard deviation for the treated and control group separately to provide an estimate of ES. The treatment group ES was subsequently divided by the control group ES to calculate the ES ratio. A ratio greater than one indicates the degree of change between the treated and control group during the pre- and postassessment interval in standard deviation units (e.g., ES = 1.46 indicates that the treated group showed a .46 standard deviation change relative to the control group between pre- and postassessment). To facilitate comparison across studies, all ESs shown in the table represent standard ES metrics (standard deviations) and indicate the degree of change due to treatment (i.e., 1 was subtracted from the resulting ES ratio metric for the pre- and posttreatment control group studies).

Substrate Versus Peripheral Variables as Targets of Intervention

The foregoing conceptual model indicates that treatments targeting the hypothesized underlying substrate of ADHD (e.g., pharmacological interventions) should produce greater comparative change in both core and peripheral variables than those targeting peripheral features of the disorder. A well-controlled therapy outcome study by Pelham et al. (1993) was selected to evaluate this prediction owing to its use of both pharmacological and behavioral interventions and inclusion of a desirable range of outcome measures.

Briefly, the study evaluated the comparative efficacy of methylphenidate (MPH; 0.3, 0.6 mg/kg) and a behavioral intervention relative to baseline performance indexes for 31 boys with ADHD attending a summer treatment program. The behavioral program targeted several peripheral variables (following rules, reducing disruptive behavior, enhancing academic performance) by means of a comprehensive behavior modification program (i.e., a point system using both reward and response-cost components, classroom rules, teacher feedback, time out, social reinforcement, contingent privileges, and a home-based daily report program). Primary dependent measures included two indexes of core variables (i.e., direct observations of on-task behavior and teacher ratings of hyperactivity) and multiple measures of peripheral variables (i.e., direct observations of disruptive behavior and following rules, teacher ratings of oppositional or defiant behavior, and seatwork completion and accuracy rates). Calculated ESs for the two core and five peripheral outcome variables are shown in Table 1. Relatively robust ESs associated with psychostimulant treatment (MPH) were obtained for both core (attention ES = 1.37, hyperactivity ES = 1.25) and four (ES range = .38–1.74) of the five peripheral outcome variables. In contrast, the behavioral intervention (focusing on peripheral variables) resulted in nonsignificant between-group differences for both core variables and moderate effects on three (ES range = .16–.18) of the five peripheral outcome variables.

Core Features as Targets of Intervention

The second set of studies shown in Table 1 focus on core variables (either attention or impulsivity) as the primary target for intervention. According to the general model, successfully affecting hypothesized core variables of ADHD (inattention, impulsivity–hyperactivity) should correspond with robust changes in outcome measures that reflect core processes as well as peripheral variables that are causally related to these processes.

Rapport et al. (1982) used the attentional training system (ATS) to improve children’s attention during classroom, in-seat academic work periods. The ATS provides points (positive feedback) on a 1-min interval basis for paying attention, coupled with teacher initiated point reductions (response cost) for nonattentive behavior. Accumulated point totals at the end of each academic session are traded for a variety of in-class activities that vary in terms of the number of earned points required for access to a particular activity. Dependent measures consisted of two core variables (teacher ratings of hyperactivity using the Abbreviated Conners Teacher Rating Scale (Werry, Sprague, & Cohen, 1975) and direct observations of attention [on-task]) and one peripheral variable (daily academic assignments completed). As shown in Table 1, robust ESs under treatment (ATS) conditions were obtained for both core outcome variables (attention ES = 2.66, hyperactivity ES = 2.21) and the peripheral variable (daily problems completed ES = 2.62) relative to baseline conditions.

The ensuing two studies targeted the core feature impulsivity. CBT, which focuses on developing self-control skills and reflective problem-solving strategies (Abikoff, 1985), was employed in both studies. Although both CBT programs were conceptually designed to reduce impulsivity, their active treatment components targeted peripheral variables such as interpersonal problem solving, peer relationships, academic performance, and anger management.

Two variations of school-based cognitive–behavioral training were compared to each other and to a wait list control condition in the Bloomquist, August, and Ostrander (1991) study. The first variation of CBT involved a multicomponent program that provided train-

Table 1. *Attention Deficit Hyperactivity Disorder Outcome Studies*

	Target of Treatment				Outcome: Core						Outcome: Peripheral	
Citation	Substrate	Core	Peripheral	ENV	Attention	ES	Impulsivity	ES	Hyperactivity	ES		ES
Pelham et al. (1993)	MPH				On-task (DO)	1.37			Iowa I/O (T)	1.25	Disruptive behavior (DO)	0.86
											Iowa O/D (T)	0.9
											Following rules (DO)	1.74
											Seatwork completion	0.38
											Seatwork accuracy	ns
			Following rules		On-task (DO)	*ns*			Iowa I/O (T)	*ns*	Disruptive behavior (DO)	0.18
			Classroom behavior								Iowa O/D (T)	0.16
			Academic perform								Following rules (DO)	0.17
											Seatwork completion	*ns*
											Seatwork accuracy	*ns*
Rapport, Murphy, and Bailey (1982)		Attention			On-task (DO)	2.66			ACTRS	2.21	Daily problems completed	2.62
Bloomquist, August, and Ostrander (1991)		Impulsivity	Interpersonal problem solving		CTRS-Inattention	*ns*	CTRS-Imp	*ns*	CTRS-Hyp	*ns*	PHSC	*ns*
					On-task (DO)	*ns*	SCRS (T)	*ns*			Social competence(T)	*ns*
			Peer relations									
			Anger management									
Fehlings, Roberts, Humphries, and Dawe (1991)		Impulsivity	Academic performance		BPC/att (P)	*ns*	SCRS (P)	*ns*	WWAS	1.12	PHSC	0.44
			Problem solving at home		BPC/att (T)	1.52	SCRS (T)	*ns*				
							MFFT RT	*ns*				
							MFFT err	*ns*				
Carlson, Pelham, Milich, and Dixon (1992)			Following rules		On-task (DO)	*ns*					Disruptive behavior (DO)	0.67
			Classroom behavior								Class points	0.86
			Academic performance								Seatwork-% complete	*ns*
											Seatwork-% correct	*ns*
Posavac, Sheridan, and Posavac (1999)			Hand raising				CTRS-Imp	*ns*	CTRS-Hyp	*ns*	Hand raising	2.73
											Talking out	2.89
											CTRS-CD	*ns*
Jacob, O'Leary, and Rosenblad (1978)				Open					H comp (DO)	0.33		

Note: ENV = environment; ES = Effect Size; MPH = Methyphenidate; DO = Direct Observation; IOWA I/O = IOWA Conners Teacher Rating Scale Inattention/Overactivity; *ns* = nonsignificant; T = Teachers; IOWA O/D = IOWA Conners Teacher Rating Scale Oppositional/Defiant; CTRS = Conners Teacher Rating Scale; Hyp = hyperactivity; Imp = Impulsivity; PHSC = Piers-Harris Self-Concept Scale; ACTRS = Abbreviated Conners Teacher Rating Scale; SCRS = Self-Control Rating Scale; BPC = Behavior Problem Checklist; P = Parents; WWAS = Werry Weiss Activity Scale; MFFT = Matching Familiar Figure Test; RT = Reaction Time; err = errors; CD = Conduct Disorder Problems; Open = open classroom; H comp = Hyperactive Behavior Code, Composite scores for Hyperactivity.

ing for parents, teachers, and children, whereas the second involved a teacher-only program. Outcome variables included measures of all three core features of ADHD (i.e., direct observations of on-task in school, teacher ratings of attention, impulsivity, and hyperactivity) and two peripheral variables (i.e., child ratings of self-concept, teacher ratings of social competence). ESs for core and peripheral outcome variables associated with the multicomponent program (compared to the wait list control group) are shown in Table 1. None of the analyses revealed statistically significant differences for individual outcome measures in comparing the multicomponent program with the teacher-only program and wait list control children. (Note that marginal effects were obtained favoring the multicomponent group when several overlapping, direct observational measures such as on-task and off-task were combined, but none remained statistically significant at follow-up assessment.)

The second study evaluated the effectiveness of CBT relative to a supportive therapy control group for improving the home and school behavior and cognitive test performance of 25 boys with ADHD (Fehlings, Roberts, Humphries, & Dawe, 1991). Outcome variables included measures of all three core features of ADHD (parent–teacher ratings of attention on the Behavior Problem Checklist attention subscale, parent–teacher ratings of impulsivity on the Self-Control Rating Scale, parent ratings of hyperactivity using a modified version of the Werry Weiss Activity Scale [WWAS], and children's performance on the Matching Familiar Figures Test) and a single peripheral variable (child ratings on the Piers–Harris Self-Concept Scale). A significant ES was obtained for only two of the seven measures of core variables (parent attention rating ES = 1.52; WWAS ES = 1.12) and the peripheral variable (Piers–Harris ES = .44). It was not possible to discern to what extent rating scale ESs obtained for the two parent ratings of core behaviors (attention, hyperactivity) were due to parental expectancy effects, as treatment focused on parent training and parents were aware of treatment objectives.

Peripheral (Associated) Features as Targets of Intervention

The third set of studies shown in Table 1 focus on peripheral variables (i.e., hypothesized causal byproducts of core features) as the primary target for intervention. According to the general model, interventions aimed at peripheral behaviors should show limited generalization upward to core features of the disorder (i.e., attention, impulsivity–hyperactivity) and minimally affect other peripheral features in terms of measured treatment effects over and above what would be expected based on overlapping behavior topographies.

Two studies were located that targeted peripheral variables associated with ADHD for purposes of intervention. The first employed a comprehensive behavior management system that included both reward and response-cost components as contingencies to improve behavior and academic performance in 24 boys with ADHD (Carlson, Pelham, Milich, & Dixon, 1992). Comprehensive behavior management was contrasted with psychostimulant treatment and a typical classroom procedure intervention (devoid of the behavior management procedures with the exception of noncontingent points based on the group's average daily point total during the preceding week). Behavioral management procedures were identical to those reported by Pelham et al. (1993) earlier and focused on providing consequences for a variety of peripheral variables such as following rules, classroom behavior, and academic performance.

Only the behavioral management component is evaluated to elucidate the breadth and magnitude of behavioral treatment effects on various outcome variables as a function of targeting peripheral variables. Outcome variables included a single measure of a core feature (i.e., direct observations of on-task behavior in the classroom) and four peripheral variables (i.e., direct observations of disruptive behavior, number of class points earned for appropriate behavior, percentage of seatwork completed and correct). Behavioral intervention failed to significantly affect the core variable (attention) but resulted in reasonably robust ES changes in two (ES = .67 for direct observations of disruptive behavior; ES = .86 for earned class points) of the four peripheral outcome variables (see Table 1).

The second study targeting a peripheral variable focused on increasing the frequency with which children with ADHD raised their hands before speaking in the context of an outpatient social skills training program (Posavac, Sheridan, & Posavac, 1999). A cueing procedure was implemented during the 8-week treatment program, the latter of which included teaching and practicing skills relevant to improved listening, interpersonal relationships, and anger management. Cueing consisted of visual reminders, goal evaluation, positive reinforcement, and constructive feedback, with the target behavior reinforced on a fixed interval basis (i.e., every 5 min). Outcome variables included two measures of core features (Conners Parent Rating Scale impulsivity and hyperactivity factors) and three measures of peripheral variables (direct observations of hand raising frequency and talking out of turn during the group sessions and Conners conduct problem ratings). The cueing procedure had no discernable effect on either of the two core variables but resulted in significant and robust improvement in two of the three peripheral measures (hand raising frequency ES = 2.73; talking out of turn ES = 2.89).

Environment as the Target of Intervention

A fourth category of studies was contrived to evaluate whether changes in the general milieu (e.g., classroom) would affect children's behavior in accord with predictions stemming from the general model. Environmental manipulations aimed at lessening demands on the underlying substrate should produce corresponding improvement in core and related peripheral variables.

A single study was located that evaluated the effects of traditional and informal classroom environments on the behavior of hyperactive children (Jacob, O'Leary, & Rosenblad, 1978). Sixteen children (8 hyperactive, 8 normal control) were observed during two, 30-min, counterbalanced class periods that were designed to resemble open (informal) and traditional (formal) teaching classrooms. During the informal class, children worked on a variety of academic related activities at their own pace and with minimal teacher involvement (i.e., limited to occasional prompting to select a task). In contrast, the formal classroom consisted primarily of having children listen to a lecture or work at their seats on academic related activities.

Direct observations using the Hyperactive Behavior Code provided indexes for several behavioral categories (e.g., solicitation, aggression, refusal, change of position, daydreaming, and weird sounds) and were complemented by Conners Abbreviated Teacher Rating Scale scores. Basic statistical information required for calculating ESs (mean and standard deviation), however, was provided only for the composite hyperactivity scores. The hyperactive children were rated as significantly more active than controls during the formal classroom period, whereas this difference was no longer apparent during the informal period (hyperactivity composite index ES = .33).

Summary of Findings and Implications for Conceptual Models

The foregoing review of outcome studies is consistent with predictions stemming from the basic conceptual model. Interventions aimed at the hypothesized substrate level (e.g., psychostimulants) produce robust treatment effects in both core (attention, impulsivity–hyperactivity) and related peripheral variables. Those targeting core variables effect significant change in core and corresponding peripheral measures. Those targeting peripheral variables effect corresponding improvement in related behavioral domains but fail to generalize to hypothesized, causally related core features. A clear picture concerning environmental manipulations that lessen demands on the underlying substrate could not be obtained owing to the dearth of published studies investigating this phenomenon and the limited range of outcome variables suitable for calculating ESs.

The glaring exception to the aforementioned pattern of treatment outcome effects was observed for the two reviewed studies involving CBT. Several explanations may account for the discrepant results. Conceptually, CBT is devised to affect the core feature impulsivity. Pragmatically, the active CBT treatment components used in treating children with ADHD focus on peripheral variables that are assumed to reflect the underlying impulsivity domain. Accepting this position, however, fails to account for the lack of expected treatment effects observed in most peripheral areas following CBT treatment, which would be expected based on the conceptual model. Thus, other explanations must be considered. One possibility is that, contrary to other behavioral interventions reported in the literature, CBT assumes that successful training and practice will produce permanent change at the substrate level, and hence, active treatment components can be discontinued following a predetermined number of training and practice sessions. In contrast, behavioral and psychopharmacological interventions are continually applied to achieve therapeutic benefit owing to a demonstrated lack of maintenance effects on discontinuation of either treatment. Thus, CBT may prove effective for a variety of peripheral variables associated with the impulsivity core if treatment components are actively administered on an ongoing basis.

An alternative possibility is that impulsivity may be incorrectly specified as a core feature of ADHD in the *Diagnostic and Statistical Manual of Mental Disorders*, despite prominent theoretical positions supporting behavioral inhibition as a central characteristic of the disorder (Barkley, 1997; Quay, 1988). For example, Denney and Rapport (2000) argued that working memory processes may better exemplify the primary core feature of ADHD, whereas the myriad behavioral and cognitive characteristics attributable to impulsivity are in fact peripheral variables or causal byproducts of deficiencies in working memory processes. The processes subsumed by the working memory construct have been implicated repeatedly in ADHD, although typically they have been viewed as correlates of the disorder rather than a set of core causal cognitive processes. A conceptual model of ADHD based on the premise that working memory constitutes a core feature of the disorder is outlined in the next section and contrasted with existing models of ADHD.

An Alternative Conceptual (Working Memory) Model of ADHD

Overview

The conceptual model is rooted in cognitive models of recognition and recall processes and working memory in particular. It also incorporates the behavioristic principle of negative reinforcement. In brief, working memory describes a set of memory processes that serve to construct, maintain, and manipulate cognitive representations of incoming stimuli. As such, it is also responsible for recognition of externally presented stimuli. In this context, recognition refers to four related processes (Glass & Holyoak, 1986). First, recognition requires that a representation of the input stimulus be constructed on the basis of its features and patterns of organization. In addition, the representation of the input guides a search of memory traces for representations of stimulus configurations that match or resemble it. Stored representations are “activated” (i.e., made available for further use) and maintained in working memory in proportion to their degree of similarity to the input representation. Finally, a comparative judgment is rendered regarding the degree to which the input stimulus matches a particular cognitive representation or set thereof. The latter process enables access to a broad network of memory traces of data related to the input stimulus, including actions appropriate to it. This facilitates organized execution of situationally relevant behavior. Evidence has accrued to suggest that these interrelated components of recognition occur in parallel rather than in a temporal sequence (Allport, 1989).

The model posits that working memory plays a pivotal role in the organization of behavior. Specifically, it proposes that organized responding is functionally dependent on the capacity of working memory to (a) generate and maintain representations of input stimuli, (b) search memory traces for matches thereto, and (c) access and maintain representations of behavioral responses appropriate to input stimuli. If these assumptions hold, disruption of any of the outlined working memory processes should result in haphazard or tangential responding to environmental stimuli.

As stated, this model may help account for the poorly structured (i.e., disorganized) behavior characteristic of children with ADHD. It does not, however, imply anything about the rate at which behavior is executed. Consequently, additional assumptions are necessary to explain why hyperactivity accompanies disorganized behavior.

A second component of the model is shown in Figure 2. The hypothesis implied in the figure is that failure of working memory not only leads to disorganized behavior but also motivates children to redirect their attention to other stimuli in the environment (i.e., a phenomenon described in the literature as *stimulation seeking*). Specifically, the inability to maintain working memory representations leads to behavior that increases the rate at which input is delivered to working memory so as to compensate for the rapid rate at which representations fade. This is a purely inductive inference based on the observations that children with ADHD demonstrate frequent, rapid shifts in activity, especially under conditions that can be characterized as monotonous or too complex to enable thorough pro-

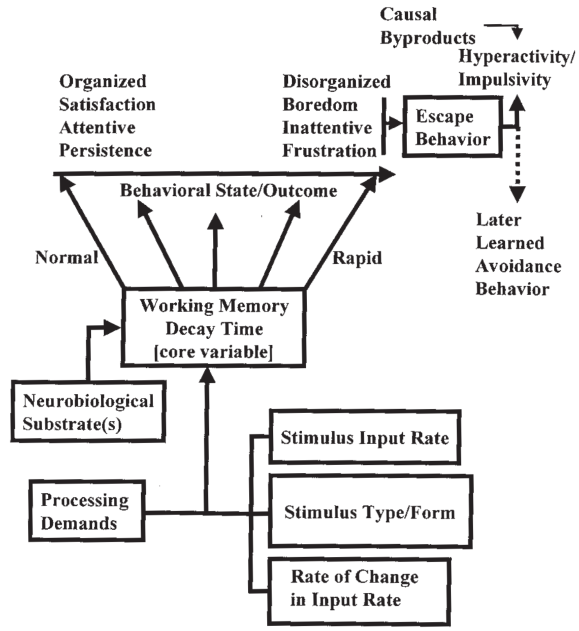

Figure 2. Hypothesized interactive relations among task processing demands, environmental and task stimuli (input rate, stimulus constancy, stimulus type or form), rate of working memory decay, and their effects on behavioral outcomes in children with attention deficit hyperactivity disorder.

cessing of stimuli. As a consequence, the rate at which stimulation impinges on working memory increases. Alternatively, redirection of attention can be conceptualized as a form of escape from monotonous or high task demand conditions and observed by others as hyperactivity and impulsivity.

Note that the model provides for precise conceptual definitions of several terms and constructs frequently invoked in descriptions or analysis of ADHD. First, the term *monotonous* is defined in this context as the property of producing low rates of working memory activity. Low rates of working memory activity may derive from either low rates of stimulus input or perceptual constancy (i.e., minimal variation in the sensory properties of stimuli). Second, the concept of *attention* is defined in terms of working memory representations. Specifically, the targets of attention at a given moment are defined by current working memory content. Thus, the model implies that the term *inattention* is without meaning except in instances where conscious activity is precluded. This view reflects the old psychological adage that “One cannot not think.” Third, the imposition of difficult task demands on a working memory system incapable of holding information to permit sufficient processing results in escape behavior owing to its aversive nature. Working memory is subsequently directed to alternative environmental stimuli to maintain a continual flow of input and observed by others as impulsive–hyperactive behavior. Finally, this model argues that consideration of consequences prior to execution of a behavioral sequence is fundamentally dependent on working memory, because the latter is the conduit through which learned behaviors find expression. Thus, impulsive acts are viewed as disorganized patterns of behavior that reflect an inability to maintain working memory representations of either the stimulus context, memory traces relevant thereto, or both.

The relation between this model and the broader conceptual framework outlined previously is shown in Figure 3. First, this model emphasizes the psychological rather than the biological features of ADHD. No specific biological substrate is directly linked to working memory deficits in the model formulated here. Working memory is simply viewed as a core causal cognitive process that is the direct consequence of one or more neurobiological substrates. This core feature is presumed to account for several peripheral characteristics of ADHD. These include disorganization, boredom, inattentiveness, and low frustration tolerance, with impulsivity–hyperactivity representing the causal byproducts of these states by means of negative reinforcement principles (see Figure 2). These features are further assumed to exert causal influences to varying degrees across a variety of other domains. Some of these, such as performance on tests of cognitive functioning are likely to be directly affected by working memory processes. Others, such as academic achievement, reflect the cumulative impact of working memory failure on component academic skills (e.g., computational ability) combined with a variety of other influences (e.g., availability of tutoring or other compensatory resources).

Model Comparisons

Although a complete theoretical analysis of extant models of ADHD is beyond the scope of this article, the working memory model will be briefly contrasted with two of these.

Cognitive–energetic model. This model is predicated on several constructs and principles. First, it posits that intra- or interindividual differences in performance on any task are causally attributable to the interaction of two sets of resources termed the *arousal* and *activation* pools. Demands on the former are operationally defined by variations in stimulus intensity and integrity (i.e., degree of degradation). Conversely, demands on the activation pool are operationally defined by manipulations of event rate and muscle tension. The activity of these two resource pools is governed by a third resource pool termed the *effort* pool. The latter is conceptually defined as “the energy necessary to modulate these two [i.e., arousal and activation] pools” (Sergeant & van der Meere, 1990). The effort pool is operationally defined through manipulation of stimulus–response compatibility.

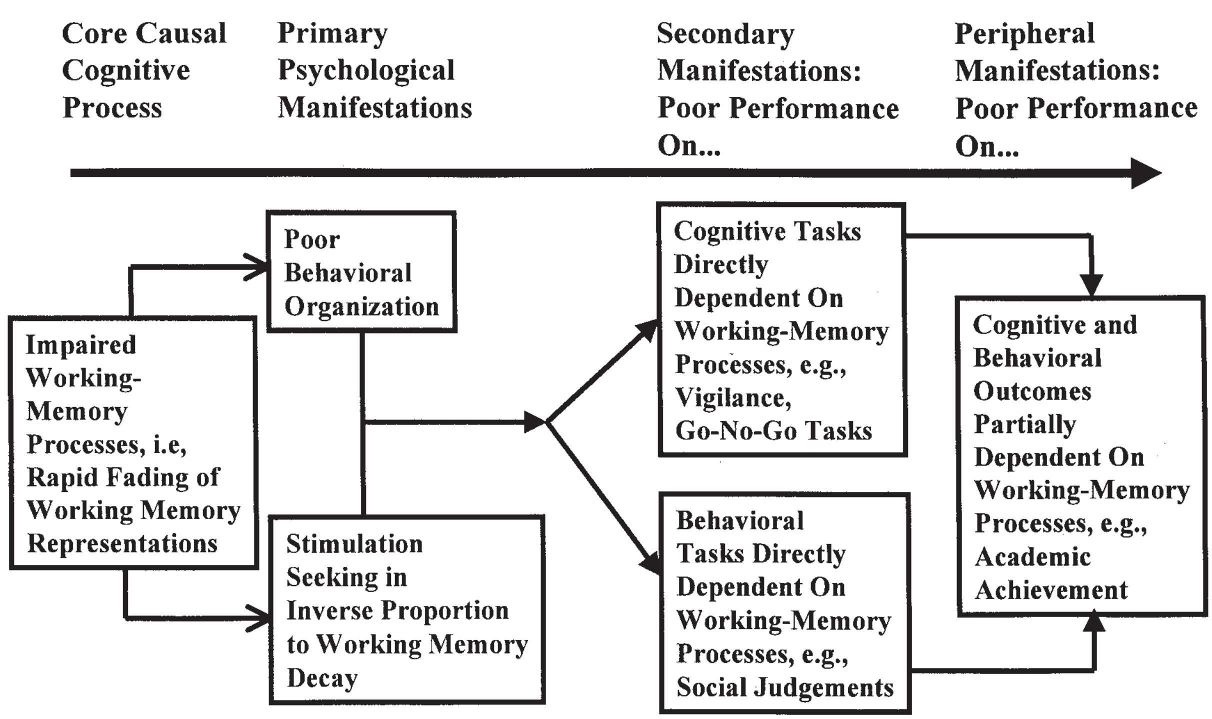

Figure 3. **Primary, secondary, and peripheral manifestations of behavior and cognition due to hypothesized working memory processing deficiencies in children.**

Sergeant and van der Meere (1990) examined these concepts using the Additive Factor Method originally formulated by Sternberg (1969) in an attempt to isolate the locus of response disorganization among children with ADHD. They concluded that the disorder is better explained by deficits in motor response selection than by encoding or decision-making processes.

Although this model is elegant in scope it is limited by several conceptual problems. First, its overarching concepts exist only in theory and do not lend themselves to any form of external validation. For example, the impact of stimulus degradation on task performance is attributed to depletion of an arousal pool, but there is no direct way to test whether an arousal pool exists at all, much less whether it can adequately be construed as a cause of poor performance. Similarly, the activation pool is presumed to control the impact of event rate on task performance, yet there is no external, verifiable standard by which to judge whether event rate affects activation. Thus, one cannot logically ascribe a causal role to the construct.

In contrast, the working memory model is predicated on constructs drawn from cognitive science that have been examined and verified repeatedly over the last 2 decades. Moreover, it emphasizes the importance of tying task parameters to specific facets of working memory function and behavior.

It could be argued that the working memory model is falsified by findings based on the cognitive energetic model. Specifically, adherents of the latter view have suggested that children with ADHD demonstrate deficiencies of motor response selection but show no deficits in encoding or decision making. These criticisms, however, warrant closer examination. First, the research reporting response selection deficiencies was predicated on the assumption that the components of stimulus evaluation, decision making, and response selection occur in temporal order. This assumption is severely weakened by data demonstrating that these processes occur in parallel and interact bidirectionally. Moreover, the broader causal attribution of response selection deficits to a “[defect of] arousal, activation, and effort” is unverifiable even granting problems with response selection.

The working memory model makes no assumptions at all about whether components of task performance occur in any particular order. It emphasizes the conceptual importance of tying task parameter manipulations to specific demands on working memory (e.g., comparative judgments) rather than invoking purely hypothetical constructs. Moreover, it posits that response selection is seamlessly integrated with recognition and classification judgements, a premise that is consistent with prevailing models of recognition phenomena such as priming. Thus, it does not dispute that children falling within the ADHD spectrum have difficulty with control of motor output. Nor does it dispute reports that children with ADHD often show no deficits in encoding individual stimuli. Rather, it argues that stimulus evaluation and response organization are part of an integrated, seamless process that goes beyond simple encoding of physical features. And, compromised ability to maintain cognitive representations derived from encoded features rather than the encoding process itself is viewed as a core feature of ADHD.

Finally, the response selection hypothesis advanced on the basis of the cognitive-energetic model addresses the issue of behavioral organization but offers no explanation as to why disorganized behavior should also be hyperactive in character. Even if explanatory power is granted to pools of effort, arousal, and activation, it is difficult to infer any way in which defects in these areas would produce hyperactivity. Hyperactive behavior usually requires acute muscular effort, high physiological arousal, and represents an extreme of activation. How then do deficiencies of effort, arousal, or activation lead to this behavioral excess? The working memory model offers an explanation for the hyperactive behavior of children with ADHD. Specifically, it posits that conditions interfering with maintenance of representations in working memory (e.g., low stimulus input) are aversive and motivate stimulation seeking. The assumption that low working memory activity is aversive is, admittedly, an inductive inference and gets dangerously close to being unverifiable to the extent that aversion is invoked as an explanatory device. The working memory model, however, emphasizes the importance of tying its assertions to manipulable task parameters. Thus, the explanatory emphasis is on the operationally verifiable hypothesis that manipulations of task parameters that control the ease with which working memory representations are generated or maintained will predictably lead to a variety of escape behaviors directed toward increasing the rate at which environmental stimulation is delivered.

Behavioral disinhibition model. Barkley (1997) recently introduced the construct of behavioral disinhibition in the context of a theoretical model of ADHD. In brief, this view asserts that the inability to suppress *prepotent* responses to stimuli interferes with the development and execution of four other executive functions, including working memory. The causal influence of disinhibition on these four cognitive features is postulated to account for the impulsive, hyperactive behavior exhibited by children diagnosed with the ADHD. Barkley’s model can easily be incorporated into the conceptual framework outlined earlier. Specifically, it asserts that behavioral disinhibition is a core causal cognitive process on which a spectrum of executive functions depend. These component processes then exert causal influences across the broad spectrum of correlates associated with ADHD.

This model is elegant in scope and emerged at a time when, as its author noted, existing concepts were unequal to the task of explaining the variety of cognitive and behavioral features subsumed by the syndrome. It is, nevertheless, weakened by a central conceptual problem. The model asserts that working memory processes and other executive functions are causally dependent on the capacity to inhibit prepotent responses. Yet, on close examination the model cannot easily account for the actual control of inhibition or lack thereof. Responses that can be characterized as disinhibited are, in fact, responses to environmental events. Inhibition does not precede but follows the registration of the environmental events. This raises the inevitable question of how sensory events lead to the action of stopping and attending. In view of the arguments and definitions advanced in the context of the working memory model, it is difficult to imagine impaired inhibitory ability without first ascribing a causal or mediating role to working memory as a primary controlling influence on inhibition. This fundamental observation lends credence to the view that disinhibition is more parsimoniously viewed as a product of working memory processes rather than a cause thereof.

Finally, the working memory model departs from both the cognitive energetic model and behavioral disinhibition approaches in a subtle but philosophically critical way. The latter views place the nexus of ADHD within the individual. Although they do not deny the contributing role of the environment in the expression of the disorder, the implicit emphasis is on characteristics that reside within the affected child. The working memory model argues that the challenges faced by affected children derive from the interaction of a diathesis (impaired working memory) with environmental conditions that impinge on it. It is our view that psychopathology expresses itself most profoundly in the face of environmental challenges and that fruitful theoretical explanations must incorporate principles that explain how and why interactions with the environment pose difficulty for affected people.

Concluding Comments

The central thesis of this article highlights the desirability of using a theoretical framework for guiding the design and evaluation of therapeutic interventions for children with ADHD. A general conceptual model was introduced as a means to evaluate ADHD treatment outcome research. Treatments designed to target the substrate level resulted in broad, robust improvement in both core and peripheral areas of functioning. Those targeting hypothesized core features of the disorder (i.e., attention, impulsivity–hyperactivity) produced corresponding improvement in core and peripheral outcome measures with the exception of studies employing CBT. And, those targeting peripheral features of the disorder effected change only in corresponding peripheral areas of functioning.

The foregoing analysis has meaningful implications for clinical practice. Designing treatments that target theoretically derived core features of a disorder should prove more efficacious than those aimed at peripheral features insofar as broad-based improvement is preferred across multiple areas of functioning reflective of core deficits. Closer scrutiny of hypothesized core features of the disorder is also warranted. Recent studies indicate that attention and impulsivity–hyperactivity, albeit clearly pathognomonic to ADHD, may not accurately reflect core features of the disorder (Denney & Rapport, 2000). Empirically based investigations that serve to link hypotheses derived from theoretical and conceptual models to manipulation of task parameters are needed to isolate and confirm core behavioral and cognitive processes central to ADHD.

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