Rule-Governed Behavior and Self-Control in Children with ADHD: A Theoretical Interpretation

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Abstract

Three theoretical models of ADHD are reviewed and interpreted in light of educational and behavioral research findings specifically in respect to interventions using self-management to address a deficit in rule-governed behavior. The perspectives considered in this paper are (a) the unified theory of behavioral inhibition, sustained attention, and EF (Barkley, 1997), (b) the cognitive-energetic model (Sergeant, Oosterlaan, & van der Meere, 1999), and (c) the dynamic developmental theory (Sagvolden, Johansen, Aase, & Russell, 2005). The perspectives are discussed in terms of the continued development of increasingly comprehensive models and the need to pursue theoretically driven behavioral and educational interventions in the future.
Keyword descriptors: ADHD, Theory, Self-Control, Self-management.

Attention deficit hyperactivity disorder (ADHD) is arguably the most prevalent neurobehavioral disorder diagnosed in children today (Fazier & Merrell, 1997; Root and Resnick, 2003; "Treat ADHD," 2002). Researchers have explored multiple aspects of the disorder including etiology, ontogenesis, and treatment options for the child population. Considering the abundance of research on ADHD, it is surprising how little of the literature on educational and/or behavioral treatment options is theoretically driven (Zentall, 2005). Historically, theories of ADHD focused on isolated, singular constructs. In the past decade, however, researchers have made significant contributions towards a comprehensive model (Nigg, 2005). As increasingly comprehensive models are developed, it will be important for behavior therapists, educators, and applied researchers to make attempts to interpret applied research findings in light of these possible perspectives to provide support for or refute these ideas.

ADHD literature focusing on educational and/or behavioral interventions typically addresses skill deficits and/or lack of motivation. The resultant research often indicates limited effects, failure to maintain effects, and little or no generalization of skills (Barry & Haraway, 2005b; Mather & Goldstein, 2001). There is little consideration of variations in etiology of the presenting behaviors or alternative explanations for the limited effects, failure to maintain effects, and failure to generalize effects that are so often reported in the literature (Barkley, 2000). Relatively recent developments in theoretical models of ADHD focusing on neurobiology and behavior provide increased possibilities for interpreting and understanding the processes that may contribute to these research findings (Sagvolden et al., 2005).

As research in the field of ADHD advances, the disorder is more often considered a deficit of self-regulation than a problem of limited attention (Nigg, 2005). Of particular interest to behavior therapists and educators is the limited acquisition of rule-governed behavior and self-control in children diagnosed with ADHD. Rule-governed behavior is behavior that is controlled by verbally mediated rules that describe the contingency between a behavior and consequence

without the actual behavior or consequence necessarily being present (Mather & Goldstein, 2001). Once behaviors are produced, they are shaped by actual contingencies that occur in practice. Behaviorally, deficits in rule-governed behavior are implicated in children with ADHD because the children exhibit appropriate behaviors when external consequences are present but fail to exhibit appropriate behaviors when external consequences are removed (Brown & La Rosa, 2002; Carlson & Tamm, 2000; Mather & Goldstein, 2001; Slusarek, Velling, Bunk, & Eggers, 2001). Thus, children with ADHD appear to be unable to follow the rules of rule-governed behavior without the consequence being immediately present. Interventions reported in educational and behavioral literature have utilized self-management strategies in which educators explicitly teach language-mediated rules designed to govern behavior to address a presumed skill deficit (Barry & Haraway, 2005a; Barry & Messer, 2003; Hinshaw & Melnick, 1992; Shapiro, DuPaul, & Bradley-Klug, 1998). These interventions are among those that consistently report limited findings when the strategies are specifically applied to children diagnosed with ADHD (Abikoff, 1991; Barkley, Copeland, & Sivage, 1980; Hinshaw, Henker, & Whalen, 1984).

In a review of literature on implementation of self-control strategies with children diagnosed with ADHD, Barry and Haraway (2005b) determined that overall increases in self-regulation were often minimal and almost always limited to reinforced trials and intervention phases when the skills were specifically taught and supported in context. Behavioral changes were reported as limited in maintenance and difficult to generalize beyond the specific intervention implementation (Abikoff, 1991; Barry & Messer, 2003; Hinshaw & Melnick, 1992; Hoff & DuPaul, 1998; Shapiro et al., 1998). Although it seems intuitive that self-management strategies would work with the ADHD population based upon their success in other populations diagnosed with behavior disorders, impulsivity, and problems with self-control (see Robinson, Smith, Miller, & Brownell [1999] for a review), other researchers have reached similar conclusions that these strategies are modestly beneficial for individuals diagnosed with ADHD (Abikoff & Gittelman, 1985; DuPaul & Eckert, 1997; DuPaul, Eckert, & McGoey, 1997; Shapiro et al., 1998).

As proposed by Barry and Haraway (2005b), it may be the case that generalization and maintenance problems are an indicator of some other factor associated with ADHD, rather than indicating that the specific intervention is unsuccessful. Barry and Haraway (2005b) couched these conclusions in Barkley's (1997) unified theory of behavioral inhibition, sustained attention, and executive functioning (EF). Their position is revisited and expanded as part of the present paper, along with further interpretation considering the following three perspectives: (a) the unified theory of behavioral inhibition, sustained attention, and executive function (Barkley, 1997), (b) the cognitive-energetic model (Sergeant et al., 1999), which incorporates the delay aversion model (Sonuga-Barke, Taylor, Sembi, & Smith, 1992; Sonuga-Barke, Williams, Hall, & Saxton, 1996), behavioral inhibition/activation (Sonuga-Barke, 2002), inhibition (Barkley, 1997), and EF (Pennington & Ozonoff, 1996), and (c) the dynamic developmental theory which incorporates aspects of previous models as well as expands the scope by including developmental, social/environmental, and neurobiological considerations in a functional analytic model (Sagvolden, et al., 2005).

Barkley's Unified Theory of Behavioral Inhibition, Sustained Attention, and Executive Function

Barkley (1997) combined aspects of behavioral inhibition, sustained attention, and EF to explain the behavioral deficits associated with ADHD. Barkley (1997, 1999), described a dysfunction in the prefrontal cortex that impedes inhibitory control and other EF in children diagnosed with ADHD. Typically, an individual's behavior is moderated by his or her internal processing of information related to the present context, past events, and anticipated future events. Barkley (2000) explained impaired EF in children with ADHD result in behavior being governed more by temporal factors such as immediate reinforcement rather than internal, self-directed processes. Thus, the impairment manifests itself in a deficiency of goal-directed and rule-governed behavior.

In terms of etiology, Barkley (1999) proposed that the impaired ability to internally regulate behavior stemmed from deficiencies in internal organization and planning processes due to a lack of inhibitory control. The EF involved in these processes were "nonverbal working memory, verbal working memory (internalized speech), the self-regulation of affect/motivation/arousal, and reconstitution" (Barkley, 1999; p. 304). In terms of nonverbal working memory, individuals with ADHD are unable to store and process information as effectively as other individuals when presented with competing stimuli (Barkley, 1997). In effect, the impaired EF disrupt the processing of information in working memory, which is a significant factor in goal-directed behavior and later affects an individual's socialization and academic skills (Zentall, Cassady, & Javorsky, 2001). For example, relative to children without ADHD, children with ADHD exhibit delays in their ability to use internalized speech or verbal thought to regulate their behavior (Barkley, 1997, 2000; Zentall, 1988). This deficiency also contributes to poor reading comprehension in children with ADHD, often presenting subsequent deficiencies in a variety of academic areas (Douglas, 1999; Zentall, Zentall, & Barack, 1978). Barkley (1999) also proposed that individuals with ADHD are more dependent on external reinforcement than internal reinforcement for motivation and task persistence, due to an inability to properly inhibit prepotent responses. The fourth EF that Barkley believed to be impaired is reconstitution, which allows individuals to analyze and synthesize internal information to generate behaviors in response to new events. As a result of the impairment, children with ADHD are less able to assemble or organize internal rules to govern their behavior.

Critics of Barkley's unified theory state that the theory is incomplete in that there is far more to the disorder than a deficit in inhibitory control and related EF (Sergeant, Geurts, Huijbregts, Scheres, & Oosterlaan, 2003). In the literature, the EF construct has been broadly defined (Douglas, 2004; Sergeant, Geurts, & Oosterlaan, 2002), and has been associated with regulating and maintaining behavior based on a context (Nigg et al., 2005) or goal (Nigg, 2001). As used by Sergeant (2000), EF was "the ability to maintain an appropriate problem-solving set for attainment of a future goal. This included such functions as: intention to inhibit a response, defer a response to a future moment, strategic planning, mental representation of a task" (p. 8). While deficits in EF were apparent in the presentation of ADHD, the deficit in EF alone was not sufficient to account for all of the presenting features associated with ADHD (Sergeant, et al., 2002; Sergeant, et al., 1999). Furthermore, Barkley's original theory did not differentiate between ADHD and other childhood disorders which also present deficits in EF and subsequent inhibitory control such as conduct disorder and high functioning autism (Sergeant, et al., 2003). Accordingly, Sergeant, et al. (2003) proposed an alternative theory, the cognitive-energetic model of ADHD (Sergeant, et al., 1999), which is also reviewed in the present paper. While not

comprehensive, the dysfunction of EF and related self-regulation deficits in children with ADHD has been well supported in the field and remains an important component in later theoretical developments (Douglas, 1989 1999; 2004; Miranda, Presentación, & Soriano, 2002; Pennington & Ozonoff, 1996; Nigg, et al., 2005; Sergeant et al., 1999; Tannock, 1998).

Cognitive-Energetic Model of ADHD

Whereas Barkley (1997) explained ADHD primarily in terms of a lack of inhibitory control and consequent deficits of EF, Sergeant, et al. (1999) argued that inhibition was not the only deficit in ADHD because problems with inhibition were not exclusively associated with ADHD. Building on the work of Barkley and others, Sergeant, et al. (2003) combined aspects of several models of ADHD within the cognitive-energetic model. Grounded in an information processing framework, Sergeant, et al. (1999) used the energetic model to explain ADHD by differentiating it from other childhood disorders.

In the energetic model, information processing efficiency was explained in terms of three ordered levels: (a) process, (b) state, and (c) management (Sergeant, 2000; Sergeant et al., 1999). Process factors were cognitive mechanisms described by the authors as "encoding, search, decision, and motor organization" (Sergeant, 2000, p. 8). In the model, state factors address the energy state of the organism and issues of activation, effort, and arousal. Management factors were the controlling processes which would include EF, working memory and, more specifically, goal-directed behavior, error detection, and planning. By addressing ADHD from multiple levels, the authors of the cognitive energetic model proposed to account for the presenting symptoms of ADHD from both a bottom-up approach from the cognitive process level and a top-down approach from the management level (Sergeant, et al., 2003).

Based on the energetic model, the deficit of rule-governed behavior observed in children with ADHD would be related to deficits at the management and energy state levels. Working memory, which has been recognized as an EF, represents information that is activated from long-term memory in relation to selective attention (Sergeant et al., 2003). A deficit in working memory is proposed as an alternative explanation to a lack of inhibitory control which would subsequently affect EF. For instance, the authors of the energetic model suggest that stimulus-response relationships may be maintained in working memory, and that the ability of an individual with ADHD to process working memory to monitor errors and make decisions to adjust his or her performance accordingly is impaired, thus inhibiting learning over time. Further, the ability to monitor errors was affected by reduced alertness (or arousal to attend to errors) and reduced ability, in terms of directed effort, to make decisions to adjust performance. Other evidence that deficiencies in regulating energy states contributed to executive disinhibition included delayed responses to time-sensitive tasks and stimuli (Nigg, 2001; Nigg et al., 2005). Nigg et al. (2005) also found evidence to support the notion that alertness or activation may be a factor in one of two (or more) neural networks involved in regulatory control in ADHD, thus affecting rule-governed behavior in the ADHD population.

According to Wilding (2005), though, the energetic model did not clearly delineate whether response deficiencies were primarily due to problems with the energetic constructs or with the processes that controlled the energetic states. Additional criticism of the cognitive-

energetic model has stemmed from questions about the nature of the stages involved in information processing and differences in these stages among children and adults with ADHD (Douglas, 1999).

Dynamic Developmental Theory of ADHD

Within a cognitive-behavioral framework, Sonuga-Barke (2005) proposed that defective reward processes due to the dysfunctional regulation of dopamine levels in the thalamocortical-basal ganglia circuits were at the heart of ADHD. This idea and others were included in a larger dynamic developmental theory by Sagvolden, et al. (2005). The dynamic developmental theory is perhaps the most comprehensive effort to date and is proposed as the most useful for understanding and interpreting behavioral and educational applied research findings on ADHD. The theorists who developed the dynamic developmental theory suggested that there were multidimensional pathways to ADHD, and they explained the differences in observed behavior in terms of differences in consequence-based behavioral processes including contingency reinforcement and extinction (Johansen, Sagvolden, Aase, & Russell, 2005). Johansen et al. proposed that hypo-functioning dopamine systems in children with ADHD resulted in less time available to allow children to associate behaviors with consequences. Consequently, children with ADHD were prone to exhibiting impulsive, hyperactive, variable, and disinhibited behaviors. Impulsivity was operationally defined by Sagvolden, et al. as both "*motor impulsiveness* [which] is presently defined as bursts of responses with short inter-response times (IRTs)" (Sagvolden, et al., 2005; p. 399), and *cognitive impulsiveness* [which] implies that private events like thoughts and plans are dealt with for short sequences of time with rapid shifts, resulting in problems with generating and following plans, problems with organizing own behavior, forgetfulness, and inefficient use of time. (p. 399).

Sagvolden et al. (2005) posited that the behaviors of a child with ADHD were a function of the interaction between factors internal to the child with ADHD (such as the functioning of dopamine systems) and environmental social factors (consequences). Variations in the within-child factors (including biological states), as well as the external conditions (including the environment), determined the behavioral state of the child at a given time. From a behavioral analytic perspective, the short-term effects of the interactions between the child and their environment produced predictable behavioral outcomes as the child developed a history of behaviors and consequences. The symptoms of ADHD would then develop over time as the child adjusted neurologically to dopamine activity.

Within the three neural circuits (prefrontal, limbic, and motor) thought to be involved in regulating attention and behavior, ineffective dopamine systems caused various deficiencies (Sagvolden et al., 2005). For example, ineffective dopamine processing in the prefrontal loop resulted in problems with directing attention and selecting behaviors. In the limbic loop, which controls reinforcement and extinction, ineffective dopamine systems caused poor stimulus control, which resulted in problems with knowing what to attend to in a given social situation as well as sustaining attention. Dopamine dysfunction in the limbic loop also resulted in problems with rule-governed behavior, and contributed to deficits in planning. Sagvolden et al. also reported that dopamine dysfunction in the motor loop caused problems in motor control, reaction

times, and response timing in their experiments. Knowlton, Mangels, and Squire (1996) also implicated dopamine dysfunction in learning and memory deficits.

Developmentally, according to Sagvolden et al. (2005), the problem in ADHD was conceptualized in the behavioral processes of reinforcement and extinction. Sagvolden et al. proposed that the presenting problems were due to (a) limited reinforcement of behaviors due to a limited delay gradient in children with ADHD, which abnormally abbreviated the time period in which learning could take place between behaviors and consequences and (b) altered extinction processes in which children with ADHD did not attend to extinction processes, thereby perpetuating the exhibition of socially inappropriate and functionally ineffective behaviors. These two processes are fundamental to learning as a child interacts within the environment through development and, as summarized, can explain to a great extent the emergence of observable ADHD symptoms. Throughout development, the inability to associate behaviors with consequences would inhibit learning in the social contexts where emerging behaviors are rewarded, punished, or extinguished depending on their appropriateness. Furthermore, the inability to establish stimulus control would lead to the observed variability in behavior and impulsiveness that is often reported in children with ADHD. This condition would then interrupt the learning of complex chains of behavior, as well. Throughout development, these altered learning processes would likely also affect language development and the processes controlled by language (namely rule-governed behavior and self-control). Taken together, these processes can account for much of the presenting behavioral symptoms of ADHD, as well as the limited findings in educational and behavioral research that attempted to teach self-regulation strategies as an intervention for these deficits.

Summary of Theoretical Models

Given that the theoretical perspectives build upon each other and incorporate previously proposed narrower views within larger models, there were few distinctions between the core assumptions of the perspectives presented. However, the theoretical perspectives did vary in the identification of core deficits in individuals with ADHD in terms of increasing scope (Sonuga-Barke, 2005). Barkley (1997) proposed that ADHD was characterized primarily by a lack of inhibitory control which had subsequent effects on related processes. From the perspective of the cognitive-energetic model, Sergeant, et al. (1999) explained ADHD in terms of failure to properly regulate the three energy states involved in alertness and vigilance in attending to and responding to a stimulus, thus also affecting EF and inhibitory control. Extending the cognitive aspects of ADHD, Sonuga-Barke (2005) combined a motivational element and focused on the function of reward processes in ADHD. Sagvolden et al. (2005) combined several aspects of the theories reviewed and incorporated development and socialization as critical factors in the presentation of ADHD across an individual's lifespan. Incorporating a variety of perspectives, Sagvolden et al (2005) encompassed etiology, ontogenesis, as well as environmental, social, and other dynamic interactions.

Taken together, these theoretical perspectives were similar in direction but described the processes from fundamentally different viewpoints. Barkley (1997) took an entirely top-down approach in describing the effects of faulty EF on subsequent behavior. In contrast, Sagvolden et al. (2005) described the process developmentally from the bottom-up using differences in

reinforcement and extinction behavioral/learning processes in relationship to the environment over time to explain the behavioral differences presented in children with ADHD. Alternatively, the main thrust of the cognitive energetic model was to encompass both top-down and bottom-up approaches in one comprehensive model. All of the approaches, however, acknowledged a deficit in inhibitory control as part of the problem, whether it was considered to be causal or symptomatic. Furthermore, each approach highlighted the altered response to reinforcement observed in children with ADHD as a fundamental symptom of the disorder.

Altogether these theoretical models offered varying perspectives on the observed lack of behavioral self-control in children with ADHD. However, the perspectives were fundamentally related on several levels. The indicated neural systems of arousal/activation, EF, reinforcement/extinction delay gradients (eventually socialization), and language skills were fundamentally related in terms of acquisition, generalization, and maintenance (Nigg, 2005). Conceptually, the perspectives pinpointed a dysfunction in related neural systems. Authors have debated, though, about the nature and location of a particular injury involved with ADHD. Among the issues that have been contested were whether the injury occurred in one location or multiple locations, whether there was one primary location that subsequently affected others, and whether any of the identified points of dysfunction were, in fact, causal or were symptomatic of something else. As the field of neurobehavioral science advances, clarity will likely emerge regarding the actual process(es) that cause and effect the behavior observed in children diagnosed with ADHD.

Reinterpreting Past Research Findings and Proposing Future Research Questions

Much of the literature base on educational and/or behavioral treatment of ADHD symptoms reflects the difficulty in demonstrating behavioral changes due to the assumption that the presenting symptoms of ADHD were due to either a deficit in skill acquisition or a lack of motivation to perform known behavioral repertoires (Barkley, 2000). Given the prevalence of ADHD, the abundance of applied research addressing the presenting deficits of the disorder, and the prevalence of limited findings in the educational and/or behavioral literature base, past findings on self-management interventions for addressing deficits of rule-governed behavior and subsequent self-control in children with ADHD are reinterpreted in the present paper using Sagvolden et al's (2005) dynamic developmental theory as a conceptual framework. Revisiting the findings on self-management in light of the reviewed theoretical perspectives reflects that acquisition is not likely the fundamental problem for children with ADHD, nor is a lack of motivation. Commonly, behavioral interventions were actually successful for children with ADHD during the treatment phase of an investigation, especially during frequently reinforced experimental trails (Barry & Haraway, 2005b; Brown & La Rosa, 2002; Carlson & Tamm, 2000; Mather & Goldstein, 2001; Slusarek et al., 2001). Success of the intervention however, was typically measured by maintenance of behavioral change over time and generalization to novel situations. Given these criteria, the effects of interventions for children with ADHD were typically reported as minimal and/or limited (Mather & Goldstein, 2001). If these results were interpreted in light of current theoretical perspectives of the disorder, previous research findings may have been viewed more positively.

Using dynamic developmental theory (Sagvolden et al., 2005) as a referent, behaviors typically symptomatic of ADHD could be explained by processes including an inability to establish stimulus control due to an altered reinforcement delay gradient and a limited working memory. It may be the inability to recall learned behaviors in context using previous knowledge to make current decisions that differentiates individuals with ADHD from their peers. Furthermore, rather than lacking motivation, these children may lack the ability to associate time variant reinforcement with a target behavior and therefore fail to associate socially appropriate behaviors with their naturally occurring social consequences. Additionally, children with ADHD may be unable to attend to extinction processes thereby continuing to exhibit socially ineffective and likely inappropriate behaviors in social contexts. If this is the case, the impaired reinforcement and extinction processes affect the learner's ability to distinguish between socially appropriate and otherwise irrelevant or ineffective behaviors. To test these ideas, future research directions should include continued investigation involving both the socialization of children diagnosed with ADHD over time and the reinforcement and extinction processes associated with socialization in comparison to other environmental factors.

One point missing from the previous discussion is the implication of the dynamic developmental theory in terms of antecedent strategies. Specifically, the authors proposed that ineffective dopamine processing in the prefrontal loop results in problems with directing attention and selecting behaviors. From a behavioral perspective, this inability to direct attention and select behaviors indicates a possible deficit in antecedent control. The perceived inattention of children with ADHD may be described in terms of this inability to discriminate relevant stimuli in a given context. In essence, these children may lack the ability to know what to attend to in a specific situation. Given this idea, teaching children specific behaviors in context, as has been done in the self-management literature (Abikoff, 1985, 1987, 1991), and then applying specific and immediate reinforcement for exhibiting those behaviors in context, would explain the research findings in which children were able to demonstrate the behaviors in context, but were unable to generalize or maintain the behavior when supports were dropped in follow-up conditions. This inability to repeat learned behaviors without specific direction from investigators may be due to the child's inability to recognize relevant cues indicating a specific behavior was relevant in a specific context to gain or avoid a particular consequence. Again, future research questions to test these ideas would include investigations of demand characteristics, closer examination of generalization and maintenance planning, and specific antecedent strategies.

While much of the literature focused on the altered ability to relate consequences to actions including the altered reinforcement delay gradient and the inability to learn from extinction processes, another important and related topic for future research may be a focus on antecedent strategies for the ADHD population. Given this understanding, primary acquisition of skills and motivation are not likely to be the fundamental deficits that we, as applied researchers, behavior therapists, and educators, should be targeting for children with ADHD. Rather, these children demonstrate deficits in identifying which behaviors are appropriate in context based on complex environmental and social cues (antecedents) as well as deficits in the processes of establishing a discriminative stimulus through reinforcement and extinction (consequences). Thus children with ADHD learn and continue to engage in a variety of behaviors regardless of social contingencies that would otherwise shape behavior in a typically developing child. Furthermore, generalization of skills, regardless of social appropriateness, to new contexts and

maintenance are affected, thus explaining the findings in previous research on self-management strategies with the ADHD population. The neural systems implicated are at the very core of an individual's ability to learn from behavioral processes of extinction and reinforcement, thus affecting acquisition of socially appropriate behaviors in context, demonstrated maintenance of skills in context, and generalization to other appropriate situations.

Previous attempts to apply self-management strategies to children with ADHD have focused on explicitly teaching language-mediated rules to control behavior in specific contexts. The participants in these studies often demonstrated the ability to perform in the specified context under highly reinforced conditions (Barry & Haraway, 2005b). Reviewing previous findings in the educational and behavioral literature on rule-governed behavior and ADHD in view of the perspectives reviewed in the present paper provides an alternative explanation of such results. Considering the theoretical perspectives reviewed, it may be that interventions should target antecedent strategies, stimulus control, generalization, and maintenance of skills as part of the fundamental deficits associated with the disorder. Specifically, establishing stimulus control prior to moving forward with a more complex behavior chain, targeting generalization of skills to new contexts using specific cues, and targeting maintenance in each context by pairing desirable behaviors with explicit and immediate reinforcement may better target the actual deficits associated with ADHD. In summary, previous applied research employing self-management strategies to address rule-governed behavior were likely incomplete by failing to address, to a large extent, both antecedent strategies and stimulus control involving consequence based interventions that took into account an altered reinforcement delay gradient and altered extinction processes specifically. Future research directions ought to address these deficits.

Other areas typically excluded in the educational and/or behavioral literature on ADHD and self-control in general and in the self-management literature specifically, are socialization and development. Increasingly comprehensive models of ADHD include development over time and socialization processes. There is some evidence that the temperament of children with ADHD may adversely affect socialization processes between children and parents (Nigg, Goldsmith, & Sachek, 2004). Over time, these interactions would likely lead to changes in behavior/consequence relationships in terms of parents implementing consequences in response to children's behavior. Other researchers have begun to explore language development variations in children with ADHD which would not only affect academics but would severely affect social skill development (Camarata & Gibson, 1999). Possible interventions to help mediate these ongoing interactions include parent education models in which a basic understanding of the processes in place and constructive strategies for altering those interactions are introduced and practiced in context with families. The relationship of altered language and social development within a family system as it relates to ADHD symptoms provides yet another future research direction.

Conclusion

Present theoretical models propose multiple pathways in terms of neurobiology and socialization that likely interact to create the observable behavioral symptoms of ADHD. The development of increasingly comprehensive theoretical models of ADHD helps to provide a framework for current and future research questions. The models will likely continue to evolve, encompassing increasing development in the areas of multiple neural processes, socialization,

environmental factors, and the interactions between these systems across the lifespan (Nigg, 2005). Presently, the research base is expanding in the areas of ADHD in adulthood (Faraone et al., 2000; Faraone, Spencer, Aleardi, Pagano, & Biederman, 2004; Sachdev, 1999; Wilens, Biederman, & Spencer, 2002) and in the female population (Seidman et al., 2006) specifically. Progressive models of the disorder will likely consider lifelong development and gender-specific etiology and ontogenesis, as well as variations of the disorder (including hyperactive, inattentive, and combined types).

Researchers continue to pursue identification of the ultimate cause of the disorder. Some researchers have approached etiology questions by attempting to rule out symptoms in adult ADHD, thus limiting their plausibility as causal factors rather than symptoms (Nigg, 2005). Other researchers continue to attempt to identify an endophenotype that is genetically linked and correlated with ADHD symptoms (Nigg, 2005; Nigg, Blaskey, Stawicki, & Sachek, 2004; Slaats-Willemse, Swaab-Barneveld, Sonneville, van der Meulen, & Buitelaar, 2003). Differential diagnosis of ADHD may also help identify causal factors by isolating symptoms and/or process dysfunctions that are associated exclusively with ADHD (Sergeant, et al., 1999).

Neurobiological research will likely continue to specify and differentiate the neural processes affected in ADHD and other disorders. Potential research questions will focus on identifying which systems break down developmentally, as well as when they break down, and if the breakdowns occur concurrently or consecutively. Continued research designed to increase the specificity of neural systems involving EF, state regulation, and other cognitive processes that are affected in ADHD will ultimately need to be linked to socialization processes that occur throughout development and mediate neurobiological factors.

In terms of rule-governed behavior, future research should focus on both antecedent- and consequence-based interventions for the ADHD population in comparison to non-ADHD samples. Further, interventions should likely include a broader scope to encompass behavioral interactions between parents and children in developing behavior patterns and ultimately socialization. Based on the theoretical perspectives reviewed, antecedent-based behavioral interventions may be warranted for the ADHD population. Antecedent strategies such as adding structure and predictability, and making rules, schedules, and routines explicitly obvious in context may help children with ADHD follow social/behavioral rules that would otherwise be established through a history of reinforcement and extinction processes in the development of rule-governed behavior. Future research should explore the effectiveness of such strategies with children diagnosed with ADHD in association with consequence based strategies while considering the altered reinforcement delay gradient and extinction processes that are also likely affected. Attempts to intervene for specific deficits demonstrated in children with ADHD should also address limitations in measuring success in terms of generalization and maintenance in environmental and social contexts.

Related to rule-governed behavior, language development is also an area for future research. Language development and the internalization of speech are imperative to the development of language-mediated rule-governed behavior, as are the socialization processes that serve to reinforce and extinguish particular behaviors. Little research has focused on language development in the ADHD population, specifically (Camarata & Gibson, 1999; Nigg,

2005). The development of pragmatic language skills may be altered in children with ADHD by the same faulty processes of learning (reinforcement and extinction). Furthermore, some symptoms of ADHD could reduce the opportunities for learning by disrupting language learning transactions and adversely impact the nature of linguistic exchanges over time throughout development (Camarata & Gibson, 1999).

In summary, the development of a comprehensive theoretical model of ADHD will require continued research to explore multiple aspects of the disorder. The field of ADHD has benefited from the diverse attempts at constructing such a model over the past 10 years. It is expected that educational and/or behavioral research and subsequent practices would also benefit from employing a theoretical model of the disorder when engineering and testing potential interventions. For interventions that are found effective, future research should investigate various combinations of strategies and the effects of treatment length as it affects children in varying stages of development, by gender, and by ADHD subtypes.

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