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Inhibitory Functioning across ADHD Subtypes: Recent Findings, Clinical Implications and Future Directions

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Abstract

Although growing consensus supports the role of deficient behavioral inhibition as a central feature of the combined subtype of ADHD (ADHD/C; Barkley, 2007; Nigg, 2001), little research has focused on how this finding generalizes to the primarily inattentive subtype (ADHD/I). This question holds particular relevance in light of recent work suggesting that ADHD/I might be better characterized as a disorder separate from ADHD/C (Diamond, 2005; Milich et al., 2001). The current paper describes major findings in the area of inhibitory performance in ADHD and highlights recent research suggesting important areas of divergence between the subtypes. In particular, preliminary findings point to potential differences between the subtypes with respect to how children process important contextual information from the environment, such as preparatory cues that precede responses and rewarding or punishing feedback following behavior. These suggestive findings are discussed in the context of treatment implications, which could involve differential intervention approaches for each subtype targeted to the specific deficit profiles that characterize each group of children. Future research avenues aimed toward building a sound theoretical model of ADHD/I and a better understanding of its relation to ADHD/C are also presented. Specifically, investigators are encouraged to continue studying the complex interplay between inhibitory and attentional processes, as this area seems particularly promising in its ability to improve our understanding of the potentially distinct pathologies underlying the ADHD subtypes.

Keywords

ADHD; subtypes; inhibition; contextual factors

Despite promising progress in our understanding of attention deficit hyperactivity disorder (ADHD), major questions remain, particularly with respect to the relations between the ADHD subtypes. Namely, initial research suggests that there may be important differences between the subtypes, leading some investigators to question whether the primarily inattentive subtype (ADHD/I) may be better categorized as a distinct diagnostic entity rather than a subtype of ADHD (Diamond, 2005; Milich, Balentine, & Lynam, 2001). However, the field remains plagued by several methodological limitations that restrict our understanding of how these groups relate to each other (Milich et al., 2001). The current

focused review examines deficits in inhibitory functioning in both the ADHD/combined and inattentive subtypes as an illustration of how interesting response patterns emerge differentiating these groups of children when investigators use clearly defined samples to study theoretically relevant areas of behavior.

ADHD Subtypes

According to the *DSM-IV*, the combined subtype of ADHD is characterized by symptoms of both inattention and hyperactivity/impulsivity. The inattentive subtype of ADHD shares clinical impairment in the domain of inattentive symptoms with the combined subtype but lacks clinically significant hyperactive and impulsive behaviors (APA, 1994). Because the diagnostic criteria for ADHD/I reflect a subset of those for ADHD/C, it is often treated as a related, but less extreme or severe variant of ADHD/C. A current controversy in the field, however, concerns whether ADHD/I is better conceptualized as a distinct disorder (Barkley, 2001; Diamond, 2005; Milich et al., 2001; Solanto et al., 2007; but see also Baeyens et al., 2006; Hinshaw, 2001; Lahey, 2001; Pelham, 2001). Questions relating to the nature and validity of ADHD subtypes are not new (e.g., Lahey et al., 1984; Lahey & Carlson, 1991) but have gained new relevance and momentum in light of recent reviews highlighting subtype differences across a wide range of clinically and diagnostically relevant variables (Diamond, 2005; Milich et al., 2001).

Although the literature on subtype differences is still developing, some noteworthy findings are emerging suggesting that ADHD/I and ADHD/C differ on several important classification dimensions. For instance, ADHD/I has been associated with unique epidemiological features including later age of onset (Faraone et al., 1998), later age of referral (McBurnett et al., 1999), distinct genetic profiles (Rowe et al., 1998; Smoller et al., 2006), and unique patterns of transmission across generations (Stawicki et al., 2006) relative to ADHD/C. Behaviorally, children with ADHD/I have been described as hypoactive, easily bored, self-conscious, unmotivated, and shy in contrast to the disruptive, impulsive behavior associated with ADHD/C (Hinshaw, 2002; Maedgen & Carlson, 2000).

ADHD/I and ADHD/C are both defined by significant impairment of attention; however, the nature of these attention problems may be distinct between the subtypes. Whereas ADHD/C is marked by distractibility (e.g., Huang-Pollock et al., 2006), ADHD/I is reportedly characterized by a “sluggish cognitive tempo,” marked by drowsiness, lethargy, and passivity (Bauermeister et al., 2005; Carlson & Mann, 2000; Milich et al., 2001). The two groups also appear to show differential types of social deficits, with ADHD/C children eliciting more social rejection, and ADHD/I children eliciting more social neglect or isolation from their peers (Hinshaw, 2002; Maedgen & Carlson, 2000). Further, children with ADHD/I are less likely to experience conduct problems but more likely to have concurrent internalizing disorders than children with ADHD/C (Nigg, 2000; Weiss et al., 2003). Finally, with respect to conventional treatment approaches, children with ADHD/I may be less likely to respond to methylphenidate treatment (Barkley, 2001; O’Driscoll et al., 2005; but see also Wilens et al., 2003), although this issue has not received the attention it deserves. Taken together, this body of research highlights areas of stark difference between

the subtypes, raising questions about the validity of conceptualizing the two constructs as related disorders.

Limitations in Research Examining ADHD Subtypes

All of the subtype differences reviewed so far must remain suggestive, however, because a critical review of the literature on ADHD subtype identifies a number of significant limitations that complicate our understanding of the disorder (Milich et al., 2001). A primary concern regarding research on subtype differences is that there is simply not much of it. Although this trend has improved somewhat in recent years, there remains a relative paucity of studies examining the inattentive subtype and even fewer involving methodologically sound comparisons between the subtypes. Other concerns and limitations from the ADHD subtypes literature include low-powered studies, neglect of the potential influences of comorbid disorders, and the use of inadequately defined subtype groups (Milich et al., 2001). The confusion generated by these limitations is further compounded by the largely atheoretical approach the field has adopted in investigating the inattentive subtype. Although promising theoretical models have been offered for the combined type (see, for example, Barkley, 1997; Nigg, 2001), their relevance for understanding the inattentive subtype is suspect.

Perhaps the most serious problem confronting the literature is that the current *DSM-IV* criteria allow ADHD/I to be conceptualized and even defined as subthreshold ADHD/C. Currently, children who have fewer than the six hyperactive/impulsive symptoms needed for a diagnosis of ADHD/C are diagnosed with the inattentive subtype. This definition of ADHD/I results in heterogeneous samples, encompassing a range of individuals from those with clinically significant inattentive symptoms but no hyperactive/impulsive behaviors, to those with similar inattentive symptoms and substantial but subthreshold hyperactive/impulsive behaviors. This contamination of groups yields results that are difficult to interpret or reconcile with other findings in the field. Recent evidence suggests this diagnostic system ultimately fails in its ability to adequately differentiate the subtype group, as illustrated, for instance, by the instability of these designations over time (Lahey et al., 2005). Some researchers (e.g., Milich et al. 2001) have recommended that future work clearly delineate the ADHD/I group so that potential differences between the subtypes of this diagnostic category can be understood better. Some strategies for accomplishing this include setting limits for the number of hyperactive/impulsive symptoms children classified as ADHD/I may exhibit, excluding children with former diagnoses of ADHD/C, and obtaining complete family history information as it pertains to ADHD and related disorders as the two subtypes seem to reflect distinct patterns of heritability (Milich et al., 2001; Stawicki et al., 2006).

Unfortunately, there has been little resolution to these issues in recent years. A systematic update of the literature is difficult at best in the absence of a systematic attempt to address these concerns and better understand the subtypes. Thus the current focused review highlights one area of the literature—studies of behavioral inhibition deficits—that serves as an exception to the largely atheoretical work on the ADHD subtypes. Although there have been numerous studies investigating various dimensions of behavioral inhibition in ADHD

in recent years, relatively few have explicitly considered subtype differences, and of those, even fewer do so in ways that differentiate ADHD/I from subthreshold ADHD/C. Therefore, we highlight a recent series of studies using clearly defined ADHD/C, ADHD/I, and comparison groups to better understand the relations between the ADHD subtypes and various facets of inhibitory performance. The research described here is not meant to be exhaustive or to represent the definitive word on subtype differences, but rather to serve as an illustrative model of how improved methodological procedures, such as carefully defining samples and assessing performance on theory driven tasks, can advance our understanding of the subtypes and translate into practical considerations for clinicians and educators.

Inhibitory Functioning in ADHD

Inhibition, broadly defined, is the process of suppressing an inappropriate behavior. Because impulsive, hyperactive, *disinhibited* behaviors characterize the combined type of ADHD, significant effort over the past two decades has focused on describing the specific nature of inhibitory deficits associated with ADHD/C (Barkley, 1997; Nigg, 2001, 2005; Pennington & Ozonoff, 1996; Quay, 1997). This research area has met with considerable success; in fact, behavioral inhibitory deficits are among the most robust and reliable in the ADHD/C literature, attesting to the importance of these impairments to the disorder (Lijffijt et al., 2005; Oosterlaan et al., 1998). However, given the theoretical differences between the impulsive nature of ADHD/C and the sluggish, inattentive characterization of ADHD/I, recent research has begun to investigate various aspects of inhibitory functioning between these subtype groups as a potentially fruitful domain through which to differentiate the subtypes (Derefinko et al., 2008; Nigg et al., 2002; Pasini et al., 2007; Scheres et al., 2001). Thus, in order to determine whether ADHD/I is better characterized as a less severe variant or, instead, as a distinct diagnostic entity from ADHD/C, researchers are increasingly focused on comparing how the groups perform on tasks purported to measure behavioral inhibition, as deficits in this area are regarded as central to ADHD/C. While still in its infancy, this area of research offers noteworthy findings that have begun to sharpen our conceptualization of the inattentive subtype (Derefinko et al., 2008; Huang-Pollock et al., 2007; Fillmore et al., in press; Nigg et al., 2002).

ADHD, Inhibition, and the Stop-Signal Task

Inhibition is largely regarded as a multidimensional construct (Nigg, 2005), and many lab-based tasks have been created to assess various aspects of inhibitory functioning (Nichols & Waschbusch, 2004; also see Nigg, 2001, Table 1). The paradigm most frequently used to study inhibitory functioning in ADHD is Logan and Cowan's (1984) stop-signal task (Nigg, 2001, 2006). In the typical stop-signal task, participants are involved in a primary task, such as quickly and accurately making differential responses to two stimuli as they appear on a screen (e.g., press one button if the stimulus appears to the right, press a different button if the stimulus appears on the left). Reaction times for this component of the task are thought to reflect the speed of the underlying response execution or "go" process (Logan, 1994). Occasionally, a tone or image (i.e., stop signal) is presented after the initial stimulus appears, indicating that participants should withhold responding on those specific trials. This task

assesses the stop-signal reaction time (SSRT), an estimate of the time it takes an individual to withhold a response, which serves as a critical indicator of inhibitory functioning: faster stopping translates to more successful inhibitions, whereas slower stopping translates to more inhibitory failures (Logan, 1994; Logan & Cowan, 1984).

Historically, a great deal of research focused on using the stop task to compare inhibitory performance between children with ADHD and controls. Two recent meta-analytic studies have reviewed performance on this task for children with ADHD across more than 30 studies (Lijffijt et al., 2005; Oosterlaan et al., 1998). In both reviews, children with ADHD demonstrated slower simple mean reaction times (MRTs) to go trials and slower SSRTs when compared to control participants. The authors interpreted the larger effect size for SSRT relative to MRT as consistent with the notion that inhibitory motor control is a central deficit in ADHD rather than more basic problems in responding generally. Despite these consistent findings, it should be noted that their generalizability to the inattentive subtype is limited by the fact that the samples either included only children with ADHD/C or otherwise included children with either subtype in a single, heterogeneous ADHD group.

To date, few studies have addressed inhibitory functioning between ADHD subtypes on the stop-signal task, although some research in this area has begun to emerge. For example, Fillmore and colleagues (in press) used a visual stop-signal task to compare inhibitory performance between carefully-defined ADHD subtype groups. Responding on the visual stop-signal tasks involves eye movements measured by an eye-tracker as the response modality rather than the traditional button-press. Results indicated that both ADHD/C and ADHD/I groups were slower to inhibit responses appropriately, and both groups were more variable than controls in the time it took them to respond overall. However, no subtype differences were observed on these measures. Similar findings emerged using a more traditional, button-press version of the task in the same sample (Adams et al., 2008). In a separate study using a version of the stop-signal task, Huang-Pollock et al. (2007) also reported impaired inhibitory control for both ADHD/I and ADHD/C groups relative to non-ADHD controls. Again, no differences were observed between ADHD/C and ADHD/I in terms of the intentional, prepotent motor inhibition measured by the basic stop-signal task.

These findings suggest that while the stop-signal paradigm has been a highly influential and informative model for studying basic inhibitory deficits in ADHD, the model is limited in its ability to differentiate the ADHD subtypes based on this method of assessing inhibitory control. Indeed, initial findings suggest that both ADHD subtypes appear to exhibit modest to significant deficits in the generalized ability to stop ongoing behavior. Thus, although the stop-signal task has been a highly influential and informative tool for studying inhibitory deficits in ADHD/C, this paradigm may not be specific enough to differentiate the ADHD subtypes. A substantial limitation of the stop-signal paradigm is that it does little to recognize the environmental context in which inhibition takes place. As such, other research has begun to use tasks tapping more subtle or complex components of inhibitory functioning, including the effect of environmental conditions preceding and following responses, and their role in the behavioral expression of ADHD.

Assessing Inhibitory Processes with Environmental Contingencies

Environmental factors can play an important role in moderating the effectiveness of behavioral control processes (Gray, 1991; Nigg, 2001, 2006; Quay, 1997). For example, stimulus cues that precede signals to inhibit or respond can facilitate the activation and inhibition of behavior by initiating preparatory processes required for the activation or inhibition of an action (Duncan, 1981; Posner, 1980; Posner et al., 1980). Similarly, the consequences following a response can influence the accuracy and efficiency of future responding. By using tasks that manipulate either the cues prior to responding or feedback contingencies following responses, it may be possible to tease apart more specific forms of inhibitory deficits in the ADHD subtypes, as well as to form a more nuanced model of how these deficits lead to characteristic behavioral symptoms of the disorder.

Preparatory Cues—Environmental cues or prompts can be helpful in directing responding by initiating neurocognitive processes involved in anticipating certain targets or response requirements. The cued reaction time task (CRT) allows researchers to study the specific role of prepotency and anticipatory mechanisms of control in the execution of behavior by manipulating cue-target pairings. On each trial, one of two target stimuli is presented—one indicates a response is required while the other indicates a response should be withheld. These targets are preceded by one of two cues. Correct or “valid” cues are those cues that correctly indicate the nature of the following stimuli (go/respond or no-go/withhold), whereas incorrect or “invalid” cues incorrectly indicate what the following stimuli will be. Valid cues tend to facilitate response execution and inhibition, as the participant is correctly prepared for the stimulus before it is presented (Fillmore, 2003).

Durston and colleagues (2007) used a form of the CRT task in a group of ADHD and comparison children and adolescents. Results indicated that although there were no group differences in overall reaction time, the ADHD group demonstrated higher reaction time variability, lower response accuracy, and significantly less improvement in response time following the valid cues relative to the comparison group. In other words, the RTs of the comparison group benefited from the valid cue but the RTs of the children with ADHD did not. These findings suggest that children with ADHD have a diminished capacity to incorporate relevant environmental information to aid their performance on basic inhibitory tasks. Unfortunately, this study did not attempt to differentiate the performance of the ADHD subtypes.

With respect to ADHD subtypes, only one study has been conducted with the CRT task. Derefinko and colleagues (2008) recently used a cued reaction time (CRT) task to explore performance between the well-defined ADHD subtypes in a sample of 9 to 12 year-old children. Consistent with stop-signal findings, children with ADHD/I demonstrated a consistently slow pattern of responding to stimuli. Additionally, results indicated that although both ADHD/C and comparison children demonstrated increased accuracy following valid (vs. invalid) cues, the ADHD/I group did not demonstrate this expected cue-dependency effect. The absence of this expected effect is remarkable because the cue-dependency effect is considered quite resilient and is evident even in the presence of behavioral disinhibition (Derefinko et al., 2008). This study suggests that in contrast to

ADHD/C and comparison children, children with ADHD/I may have more pronounced deficits in applying preparatory information from the environment to direct their behavior. This finding demonstrates a deficient aspect of information processing that could account for inhibitory control problems in ADHD/I and should be explored further in future work.

Response Contingencies—Just as cues preceding stimuli can impact response accuracy, reinforcing or punishing feedback following a response can influence subsequent behavior (Gray, 1991; Nigg, 2006). Motivational models suggest that behavioral inhibition can be facilitated in response to anxiety- or fear-inducing feedback or, alternatively, in response to highly rewarding consequences. Though several models have been posited to explain this phenomenon, Newman and Wallace's (1993) response modulation model has received substantial attention in the ADHD literature in recent years. The response modulation model incorporates the behavioral activation (BAS) and inhibition (BIS) systems originally described and later updated by Gray (1991). The BAS is a theoretical system responsible for activating approach behaviors following rewarding feedback, whereas the BIS activates inhibitory processes following punishment (Gray, 1991). Some have speculated that the problems exhibited by children with ADHD/C may derive from an overly active BAS, whereas children with ADHD/I may be characterized by an especially strong BIS (Milich et al., 2001; Quay, 1997). The response modulation hypothesis proposes that individuals are constantly evaluating feedback from the environment to inform their future behavior. According to this model, deficits in behavioral inhibition are the net result of weak BIS activity in tandem with dominant BAS activity (MacCoon et al., 2004; Patterson & Newman, 1993).

Response modulation is assessed using tasks such as a mixed contingency (i.e., reward and punishment) go/no-go task (GNG; Newman & Wallace, 1993), where correct responses elicit rewards and incorrect responses result in punishment. Such GNG tasks allow researchers to assess the influence of consequences on the efficiency and accuracy of inhibitory performance. The response modulation hypothesis suggests that rewarding feedback will be more influential in driving response patterns for individuals with ADHD/C than punishing feedback, resulting in increased errors of commission, or failures to inhibit responses to stimuli that evoke punishment. In this sense, individuals with response modulation deficits are so dramatically influenced by rewards they are incapable of stopping reward-driven behavior even when the contingencies change.

Three studies have found that children and adolescents with ADHD/C demonstrate increased commission errors on basic GNG tasks, although it remains unclear how contingency conditions impact performance. Iaboni et al. (1995) found that ADHD/C children made more commission errors across reward, punishment, and mixed contingency conditions, but did not differ from controls in the number of omission errors (incorrectly withholding a response) made. In contrast, Hartung and colleagues (2002) and Milich et al. (1994) found that on a GNG task, adolescents with ADHD/C made more errors of commission in mixed contingency, but not in punishment-only conditions, offering support for the response modulation hypothesis.

Few studies have examined the influence of response contingencies on the performance of children in the two subtypes. In a study examining the influence of reward contingencies on inhibitory performance between the ADHD subtypes, Huang-Pollock et al. (2007) reported that children with ADHD/I, but not children with ADHD/C, showed improved performance in a reward-only task. Derefinko and colleagues (2008) used a GNG task with mixed contingencies (i.e., reward and punishment) and found a unique response pattern for the ADHD/I group relative to their ADHD/C and comparison peers. Specifically, the ADHD/I group demonstrated longer response reaction times and more errors of omission, suggesting a slow, perhaps cautious response style in the face of reward and punishment. Notably, in both studies children with ADHD/C group failed to improve inhibitory performance in response to feedback whereas children with ADHD/I demonstrated such improvement. Thus it may be the case that ADHD/C involves the inability to appreciate or incorporate information immediately following a response that would otherwise guide or direct future behavior.

Summary

Though relatively few studies are summarized above, their ability to detect differences between the ADHD subtypes is promising. Based on the findings described above, several key points can be identified with respect to areas of apparent convergence and divergence between the ADHD subtypes: 1) both ADHD/I and ADHD/C demonstrate some inhibitory deficits (i.e., slower SSRT) relative to non-ADHD comparison peers, as measured by the stop-signal task; 2) ADHD/I is consistently characterized by a slow, perhaps even cautious response style, which may affect inhibitory functioning; 3) children with ADHD/I may have unique deficits in processing environmental cues to direct behavior; and 4) children with ADHD/C may have unique difficulties in incorporating rewarding or punishing feedback to improve inhibitory performance. Broadly, it seems that while both ADHD subtypes evidence some impairment in the area of behavioral inhibition, each is characterized by a unique pattern of performance deficits when environmental contextual factors are considered.

Another clear conclusion from this literature is that there seems to be limited utility in discussing behavioral inhibition as a singular or unitary construct with respect to deficits in ADHD. Rather, greater insight into the nature of the disorder—especially with regard to subtype differences—is gained through a more systematic, multi-task approach that keys in on specific dimensions of inhibitory functioning particularly with respect to complex environmental contextual factors.

Clinical Implications

The evidence reviewed identifies potentially important differences in the response of the two subtypes to information in the environment. If these suggestive findings are supported by future research, they may have different treatment implications for the two groups of children. Some recent work has tested whether current conventional treatments (i.e., behavioral management training, stimulant medications) are equally effective across subtypes. Findings from this literature are somewhat equivocal, highlighting the need for further investigation (Barkley, 2001; O'Driscoll et al., 2005; Wilens et al., 2003). While

most treatment studies with ADHD/I have tested response to existing treatment options, a few have generated novel intervention strategies focused on addressing the unique features of ADHD/I. For example, Pfiffner and colleagues (2007) developed a behavioral psychosocial treatment program aimed at addressing unique features of inattention and sluggish cognitive tempo common in ADHD/I. Results suggest that the program, which involved the children, their parents, and teachers, was effective in reducing symptoms and increasing positive social and organizational skills relative to a no-treatment control group. Although the lack of a treatment-as-usual control group limits our understanding of how this novel treatment approach compares to conventional approaches, it is encouraging that investigators are working to develop and refine effective treatments specific to ADHD/I. Further work is needed to determine whether other strategies based on the specific subtype deficits identified earlier in this paper may be even more beneficial in treating both the symptoms and the underlying causes of ADHD/I.

Researchers are encouraged to continue developing theoretically driven, empirically supported treatment strategies to help ameliorate the degree of impairment experienced by children with ADHD. The results described above regarding differential inhibitory deficits between the subtypes suggest that unique treatment plans may be warranted to address these unique areas of impairment. For example, based on the findings described above, children with ADHD/I do not seem to appreciate environmental cues presented prior to responding. It may be that the ADHD/I group is simply slower to process contextual information, and thus would require greater time before responding. Alternatively, consistent with parental and teacher descriptions of children diagnosed with ADHD/I as daydreamers who at times appear lost in their own thoughts, these children may not be attuned to environmental cues and thus would require special help recognizing these potentially valuable prompts. Because inhibitory functioning in children with ADHD/I improved with both rewarding and punishing feedback (Derefinko et al., 2008, Huang-Pollack et al., 2007), the use of clearly delineated behavioral contingencies may be particularly helpful in improving behavior in this group.

Conversely, children with ADHD/C do not seem to appreciate information provided from the environment following responding, and thus may require unique interventions or accommodations focused on addressing this deficit. The inability of the ADHD/C group to respond to feedback in normal ways signals the importance of altering contingency systems to be most effective. Clear, salient rewards and punishments, in conjunction with cues prior to onset of behaviors, will likely be helpful in diminishing the impact of these inhibitory deficits on the daily lives of children with ADHD/C.

Additionally, assessment practices should be theoretically-driven and informed by empirical evidence. To promote diagnostic clarity, it may be helpful to tailor assessment tools to focus more specifically on specific areas of impairment unique to each subtype. Possible targets for differential assessment might be symptoms of “slow cognitive tempo” characteristic of ADHD/I or any of the various aspects of response style characteristics summarized above.

Future Directions

Despite increased interest in the inattentive subtype of ADHD, particularly in the area of inhibitory functioning, a number of important problems remain unresolved. Foremost among the implications of this line of research is the clear need for a comprehensive model of ADHD/I that incorporates etiological and pathological mechanisms into a cohesive framework for understanding the disorder. Recent research indicates a complex pattern of discontinuity between the ADHD subtypes, rendering existing models of ADHD incomplete. Effectively, a concerted effort focused on exploring and validating the construct of ADHD/I is needed to address the myriad unanswered questions surrounding the disorder. Among the most rigorous strategies for this kind of theory building is careful and systematic testing of competing hypotheses to define and test the nomological net surrounding the diagnostic construct. Such a model may then be critically tested in future investigations using carefully defined groups of children with each ADHD subtype and controls. It may be helpful to start with existing models of ADHD (e.g., Barkley, 1997; Nigg, 2001) and evaluate them with an eye specifically to their validity in characterizing ADHD/I. In identifying areas of convergence and divergence between ADHD/I and other constructs, it will be important to continue comparing the disorder with ADHD/C, but also with other internalizing and externalizing disorders as well as developmental disorders such as learning disabilities. A multidisciplinary approach combining expertise in cognitive, developmental, physiological, and clinical science will likely be beneficial in this regard.

Researchers are encouraged to address several of the aforementioned concerns with the existing literature (Milich et al., 2001) by controlling for variability in sampling procedures, applying theoretically-driven principles to build a cohesive set of data, and assessing performance on a wide variety of tasks designed and selected to measure a range of performance variables subsumed under the heading of response inhibition. It also will be valuable to evaluate systematically the heterogeneity of the group currently diagnosed as having ADHD/I (Nigg, 2005). Obviously, replication and extension of several of the findings reported earlier are required for the purposes of validating a model of ADHD/I, but we propose this approach as a valuable step toward clarifying the nature of the disorder.

Just as it is important to undertake detailed analyses of subtype differences in inhibitory behavior, problems in attention may eventually prove equally important and informative in terms of explaining patterns of impairment and areas of discordance between the ADHD subtypes. An especially promising line of investigation is the role of inhibitory processes in regulating attention. An example of this phenomenon is the inhibition of return (IOR) effect, whereby individuals are slower to look at a location where a target has already been presented owing to an evolutionarily driven reflex to maximize efficient scanning of the environment (Klein, 1988; Posner & Cohen, 1984). Typical performance on IOR tasks predicts that participants automatically or reflexively inhibit looking in areas that have already been examined to promote search efficiency (Posner & Cohen, 1984). Fillmore et al. (in press) studied the nature of this effect in a sample of children with ADHD/I, ADHD/C, and a comparison group. They found that the comparison children clearly showed the effect, as evidenced by longer reaction times to stimuli presented in the same location as previous targets. Interestingly, the IOR task was useful in discriminating between ADHD subtypes.

While both ADHD groups demonstrated diminished reflexive inhibition relative to the comparison group, the ADHD/C group showed absolutely no evidence of an IOR effect whereas children with ADHD/I showed the effect although not to the degree shown by comparison children. Therefore, on a measure of inhibitory effects on attention, ADHD subtypes again demonstrate divergent patterns of deficits, which may be indicative of differential underlying pathology. This is particularly interesting given that the demands of the IOR task reflect an interface between inhibitory and attentional functioning, both of which are considered core features of ADHD.

Our discussion of differential response patterns across ADHD subtypes is necessarily limited by the fact that we only address measures of inhibitory functioning. However, several other clinically relevant variables also have been proposed as important to the neurocognitive profiles of ADHD subtypes. Among the most likely candidates for the deficits observed in ADHD/I are working memory (Diamond, 2005), attention (Huang-Pollock et al., 2005; Huang-Pollock et al., 2006), motivation (Quay, 1998), various executive functions (Nigg et al., 2002; Pennington & Ozonoff, 1996), and the complicated interplay among these processes. Given the complexity of each of these constructs and the presumed mechanisms that underlie them, this is at once an exciting albeit daunting undertaking. However, as the results reviewed here suggest, such an undertaking can be fruitful and informative in increasing our understanding of the similarities and differences between the two subtypes.

Implications for *DSM-V*

The suggestions described above reflect the need for improvements in the way the field defines ADHD and related disorders. The *DSM* plays an important role in guiding research and directing clinical care related to ADHD. With a revision currently in progress, it is prudent to consider how the findings described above might influence how *DSM-V* should address the ADHD subtypes. First, the current diagnostic criteria do not seem to adequately differentiate individuals with ADHD/I from those with subthreshold ADHD/C. Thus, to appropriately and effectively identify these individuals, the new diagnostic criteria may need to incorporate additional symptom categories. Adding variables such as sluggish cognitive tempo (Bauermeister et al., 2005; Carlson & Mann, 2002; but see also Todd et al., 2004), or other, more specific forms of cognitive processing deficits could provide a clearer distinction between the subtypes. As an additional classification criterion for ADHD/I, limiting the number of hyperactive/impulsive symptoms has also been shown to be an effective strategy for differentiating this group from subthreshold ADHD/C (e.g., Derefinko et al., 2008; Fillmore et al., in press). Family history information may also be important to include, as children diagnosed with ADHD/I have relatives with both ADHD/I and ADHD/C, but children with ADHD/C tend only to have relatives with ADHD/C (Stawicki et al., 2006). It is likely that the heterogeneity of the ADHD/I group's family history profile corresponds to the heterogeneity of the group itself, whereby "pure" ADHD/I individuals may have relatives with ADHD/I and individuals with subthreshold ADHD/C have relatives with ADHD/C. By more explicitly taking this additional information into account as part of the diagnostic process, researchers and clinicians may be more successful in differentiating the subtype groups.

The *DSM-V* task force should also consider softening the strict reliance on cutoff scores promoted by the current manual. Although it is helpful to have a general framework for determining clinically significant impairment, a rigid adherence to arbitrary cut-offs (cite DBD report), without correction for influential demographic variables such as age and gender, measured using fallible indicators, to make absolute judgments can muddy the diagnostic waters as much as it clarifies them. This is particularly true from a theoretical perspective, as cutoff scores reinforce the subthreshold model of ADHD/I. It may instead be helpful to adopt a more dimensional approach to defining the ADHD subtypes or at least offer ranges rather than absolute cut-offs. This approach follows recent suggestions to conceptualize other forms of psychopathology, particularly personality disorders, as continuous constructs rather than discrete categories (i.e., Widiger & Trull, 2007). In such a model, it might be possible for someone to demonstrate deficient performance or impairment in areas that characterize ADHD/I, ADHD/C, both, or neither. This paradigmatic shift would allow a richer, more nuanced picture of the individual, while acknowledging that some people with ADHD/C may not demonstrate equally severe or impairing symptoms across categories. Thus children with subthreshold ADHD/C could be diagnosed as such, and not be classified in the same group as children with ADHD/I. In any event, it will be important for researchers to explicitly test these options to determine the optimal framework for describing and differentiating these diagnostic groups.

Alternatively, rather than continue to conceptualize ADHD/I and ADHD/C as subtypes of the same disorder, it may be more appropriate to place the two groups in separate diagnostic categories altogether. This raises the question of where the group currently designated as the primarily inattentive subtype would best fit in the overall diagnostic framework. Based on descriptions of these children as being hypoactive, somewhat shy, and less difficult for parents and teachers to manage, it seems inappropriate to categorize ADHD/I as a disruptive behavior disorder as is currently the case. One option would be to categorize ADHD/I as a developmental disorder, similar to learning disabilities, reflecting the apparent deficits in information processing that characterize the group. Wherever the group fits into the new framework, it will be important for researchers to continue investigating the nature of this construct to better understand how those individuals with the disorder can best be identified and provided appropriate therapeutic and educational services.

As this brief review demonstrates, theory-driven studies of carefully defined, homogeneous groups can identify potentially important differences between the ADHD/I and ADHD/C subtypes. However, until investigators adopt a new diagnostic approach, the field will remain stymied by confusion and inconsistent findings.

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