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thesis entitled

COGNITIVE INHIBITION IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER SUBTYPES

presented by

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has been accepted towards fulfillment
of the requirements for

M.A. degree in PSYCHOLOGY

Major professor

NOVEMBER 11, 2002
Date

COGNITIVE INHIBITION IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER SUBTYPES

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A THESIS

Submitted to
Michigan State University
In partial requirements
for the degree of

MASTER OF ARTS

Department of Psychology

2002

ABSTRACT

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Child ADHD has three current subtypes: predominantly inattentive, hyperactive-impulsive type, and combined. Leading theoretical models of ADHD do not adequately address neuropsychological differences between these subtypes, nor the potential distinction between motor versus cognitive inhibition . The first three studies were conducted to develop directed forgetting task procedures and evaluate results in adults and fourth grade children. Results indicated that children were in a transitional phase of development, only capable of partial inhibition of to be forgotten (TBF) items. The fourth study evaluated children with ADHD-C and ADHD-PI subtypes and control children with regard to cognitive inhibition. Three groups of children (ADHD-C: n = 33, male = 78.8 %, mean age = 9.8 years; ADHD-PI: n = 15, male = 53.3 %; mean age = 10.2 years; control: n = 27, male = 51.9 %, mean age = 10.0 years) completed the directed forgetting procedure. Children again recalled few TBF items, suggesting an inhibitory ability. The presentation of TBF items interfered with recall of "to be remembered" (TBR) items, again supporting the notion that these children were in a transitional phase of development with regard to ability to suppress material from working memory. No evidence of a cognitive inhibitory deficit was found in the ADHD groups. Along with other studies this suggests that ADHD is not characterized by a deficit in cognitive inhibition in middle childhood. Future research will investigate whether such an ADHD deficit will emerge as children develop.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Joel T. Nigg, for all of his help and encouragement with this thesis. I would also like to thank all of the students and staff working on MSU Attention Studies for their support in general and for helping with data collection.

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Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common childhood behavior disorders. Current estimates of prevalence indicate that 3 to 7% of children meet the diagnostic criteria for ADHD (Pelham, 1997). Boys outnumber girls by approximately 3 to 1. This disorder can have significant effects on children's academic and interpersonal functioning and is related to a host of long-term social, academic, and behavioral problems (McGee, Partridge, Williams, & Silva, 1991; Vaughn, Hogan, Lancelotta, Shapiro, & Walker, 1992).

ADHD is a fairly heterogeneous disorder characterized by symptoms of hyperactivity, impulsivity, and inattention that are extreme for developmental age, are persistent, and cause impairment in multiple situations. In addition, onset must occur early in life, with some impairing symptoms present before age 7. The most recent diagnostic criteria, as described in the fourth test revision edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR, American Psychiatric Association, 2000), require that a child have at least six inattentive and/or six or more hyperactive-impulsive symptoms (out of nine from each category) for a diagnosis of ADHD. Somewhat organizing this heterogeneity, a child might be categorized into one of three different subtypes: predominantly inattentive, predominantly hyperactive-impulsive, or combined type.

Children with the inattentive subtype of ADHD often make careless mistakes, have difficulties sustaining attention, are forgetful, and are distractible. Furthermore, they are often (but not necessarily) hypoactive and appear sluggish. Conversely, children with the predominantly hyperactive-impulsive subtype tend to be fidgety, talk excessively, and

run around at inappropriate times. They often have difficulty awaiting their turn, blurt out answers, and interrupt others. Children with the combined type of ADHD exhibit high levels of both inattentive and hyperactive-impulsive behaviors. It must be noted that the hyperactive subtype of ADHD will not be featured in the present study due to its possible pre-school developmental status, and apparent rarity in school age children.

The current subtype classification system was new in DSM-IV (APA, 1994; 2000). Unlike prior editions, the DSM-III-R (APA, 1987) did not distinguish between ADHD subtypes, which was problematic because observations of children by clinicians and researchers supported subtype distinctions. The previous edition (DSM-III, APA, 1980) did classify children with the disorder based on the presence (ADD+H) or absence (ADD-H) of hyperactivity. Yet the differentiation of the subtypes in DSM-III differed somewhat from that in DSM-IV, as described below. Therefore, more research is needed on this new subtype classification system. To avoid confusion in the discussion of these subtypes, the following terms will be used: "predominantly inattentive" or "ADHD-PI" will refer to children with mainly inattentive symptoms; "combined type" or "ADHD-C" will refer to children with inattentive, hyperactive, and impulsive symptoms. The term "ADHD" will refer to the disorder in general when subtype distinctions are not germane.

As just noted, it is important to keep in mind that these terms were operationalized differently depending on which version of the DSM was in use. For example, unlike the DSM-IV, DSM-III required that both hyperactive and inattentive children exhibit impulsive behavior in order to receive a diagnosis of ADD. In addition, only three hyperactive or three inattentive symptoms were needed to meet the criteria for ADD + H or ADD - H under DSM-III. DSM-IV requires the presence of six inattentive

or six hyperactive/impulsive symptoms for diagnosis. Thus, the inattentive group identified in DSM-IV may be somewhat different than the inattentive group identified in DSM-III. Milich et al. (2001) reviewed the scant literature on the correspondence between ADHD subtypes across versions of DSM and argued that the DSM-III inattentive subtype corresponds fairly well to the DSM-IV subtype with respect to diagnosing clinic referred samples. Nonetheless, new data on cognitive mechanisms in this subtype are needed.

Differences in ADHD Subtypes

Behavioral differences between ADHD subtypes

Initial evidence in support of the validity of subtypes in the diagnosis of ADHD was based on the DSM-III classification. Different outcomes are reported for children with hyperactivity and impulsivity versus children with inattention only. Shaywitz and Shaywitz (1993) found that inattention, more than hyperactivity or impulsivity, was related to later school failure. Conversely, hyperactivity and impulsivity in children were related to additional aggression and conduct problems as well as peer rejection (Lahey & Carlson, 1991). Similarly, Lahey and Colleagues found that ADHD-C children had more peer-related problems and were more unpopular than children with ADHD-PI, using DSM-III criteria (Lahey et al., 1984).

The inattentive and combined subtypes of ADHD also have different comorbid disorders more frequently associated with them. Lahey (1988) found that children with ADHD-C were more likely to be diagnosed with comorbid conduct disorder, whereas children with ADHD-PI were more likely to be diagnosed with a comorbid anxiety disorder. More recently, Eiraldi, Power, and Nezu (1997) found that children with the DSM-IV combined type of ADHD were more likely to have a comorbid diagnosis of oppositional defiant disorder or conduct disorder and were rated by both teachers and parents as having more externalizing behavior problems than the inattentive group.

Barkley, DuPaul, and McMurray (1990) examined two ADHD groups (ADHD-C and ADHD-PI) who were subtyped by DSM-III criteria, as well as a learning disabled group and a community control group. Children with ADHD-C had significantly more symptoms of ADHD, oppositional defiant disorder, and separation anxiety disorder than

the other three groups. Children with ADHD-PI had significantly more ADHD and oppositional defiant disorder symptoms than did the learning disabled and control groups. Moreover, children with the predominantly inattentive subtype of ADHD had significantly more symptoms of major depressive disorder than did the other three groups. By maternal report, children with ADHD-PI were more likely to have maternal relatives with anxiety disorders than the other three groups. Conversely, children with ADHD-C were more likely to have maternal relatives with more substance abuse problems and paternal relatives with attention deficits and hyperactivity.

In a rather comprehensive review of the literature on ADHD and attention to that time, Schaughency and Hynd (1989) concluded that children who are inattentive but who do not exhibit high levels of hyperactivity are different in many respects from children who are hyperactive and inattentive. In a more recent review of the literature on ADHD subtypes, Milich et al., (2001) argued even more strongly that ADHD-PI is indeed a distinct disorder, in part because of the differences (described above) in behavior and comorbid conditions associated with ADHD-PI and ADHD-C. They reasoned that these differences support the distinctiveness of this ADHD-PI as a diagnostic group. Other investigators (e.g. Hinshaw, 2001; Lahey, 2001) pointed out in response that although it may be a somewhat premature to draw such a conclusion about the inattentive subtype at this point, it is important to investigate further whether ADHD-PI is a valid subtype of ADHD or a separate disorder. In summary, the inattentive and combined types of ADHD are behaviorally dissimilar in several respects, for example in school and social outcomes and common comorbid disorders, lending support to the validity of distinguishing them as separate subtypes, or possibly separate disorders. Data that can potentially illuminate

whether they have shared or distinct psychological (cognitive) processes are of keen interest.

Neuropsychological differences between ADHD subtypes

As Barkley (1997) suggested, the inattentive versus combined types of ADHD might reflect impairments in different kinds of attention or other cognitive processes. For example, he suggested that deficits in selective attention are related to the predominantly inattentive subtype, while distractibility and sustained attention are impaired in the combined type. This distinction does not follow current attention theory in which distractibility and sustained attention are considered aspects of selective attention. The current study, while not relying on Barkley's distinction, could provide data to evaluate it. Schaughency and Hynd (1989) argued that some of the deficits present in children with ADHD are related to functioning in specific regions of the brain. They suggest that cognitive or neuropsychological mechanisms may also differ by subtype. However, relatively few data by which to evaluate claims of this nature are available for the DSM-IV subtypes.

Faraone and colleagues (1998) evaluated differences in IQ scores and academic achievement between subtypes in a large sample (n = 301) of clinic-referred ADHD children. Full Scale IQs, as well as Wechsler subscale factors such as the Freedom From Distractibility Index, a measure of the ability to attend and concentrate, did not differentiate the subtypes although both the ADHD-C and ADHD-PI groups were significantly worse than controls. Similarly, Arithmetic and Reading scores failed to differentiate the ADHD groups. The ADHD-PI group had significantly lower Arithmetic scores than controls, and the ADHD-C group's Arithmetic and Reading scores were both

significantly lower than controls. However, these tests did not necessarily tap relevant cognitive functions such as inhibitory or attentional processes.

Barkley et al. (1990), mentioned earlier, also looked at neuropsychological differences in ADHD subtypes, including a continuous performance test (CPT; Gordon, 1983). During this nine-minute test, children viewed a screen on which numbers appeared. Children were instructed to press a button every time the number "1" was followed immediately by the number "9" on the display. Due in part to the variance of responses within the groups, the number of correct responses, omissions (failure in responding to the target combination), and commissions (responding in the absence of the target combination) made by ADHD-C and ADHD-PI children was not significantly different. However, the ADHD-C group made almost twice as many errors of commission as the ADHD-PI group.

Like Faraone et al. (1998), Barkley et al. (1990) reported that the two ADHD groups were not significantly different with respect to Wechsler Intelligence Scale for Children – Revised (WISC-R; Wechsler, 1974) Full Scale IQ and Wide Range Acheivement Test – Revised (Jastac & Jastac, 1978) subscale scores, although these scores were significantly lower than those of the control group. The Kagan Matching Familiar Figures Test (Kagan, 1966), often used as a measure of impulse control, also did not differentiate among the four groups in the study. However, children with the inattentive subtype performed significantly worse on the Coding subtest if the WISC-R than did the other three groups.

Because of the high degree of comorbidity in ADHD, it is important to determine if the executive functioning deficits usually found in children with ADHD are the result

of the ADHD, comorbid conditions, or both. Klorman et al. (1999) evaluated executive functioning deficits in children with ADHD, oppositional defiant disorder, and/or reading disorder. On the Tower of Hanoi (TOH), children with ADHD-C made more rule violations and solved fewer puzzles than children with ADHD-PI or controls, suggesting deficits in planning and goal management in this group. On the Wisconsin Card Sorting Test (WCST), a measure of set shifting, children with ADHD-C made more nonperseverative errors than did ADHD-PI children. The authors concluded that executive functioning deficits were only demonstrated by the ADHD-C group, and were independent of comorbid oppositional defiant disorder or reading disorder. Similarly, Houghton et al. (1999) evaluated executive functioning deficits in children with ADHD without comorbid conditions. They asserted that the ADHD-C group alone had executive functioning deficits, and because they excluded children with comorbid conditions from the study, these results were independent of comorbidity.

Nigg and colleagues (2002) investigated ADHD subtype differences with respect to deficits in executive functions. The Tower of London, Stop Task, Trailmaking Test, and Stroop task were completed by ADHD-C, ADHD-PI, and control children. On the Stop Signal Task, ADHD-C children had a slower reaction time, a measure of behavioral inhibition, relative to controls regardless of gender. In contrast, only ADHD-PI girls had such a deficit relative to controls. When comparing ADHD-C and ADHD-PI groups, Nigg et al. found that while the girls in the ADHD groups did not differ in their stop signal reaction times, ADHD-C boys were slower than ADHD-PI boys. These data suggested that the two subtypes might differ with regard to motor inhibition. On the Tower of London, a measure of planning, ADHD-C children demonstrated a large deficit

relative to controls. While the two ADHD groups did not differ, ADHD-PI children did not have a significant deficit relative to controls.

Neither ADHD group demonstrated impairment in interference control on the Stroop Test, although both groups showed impairment in naming speed. Finally, Nigg et al. (2002) reported that neither group demonstrated a deficit in set shifting on the Trailmaking Test. However the ADHD-PI demonstrated a deficit in output speed relative to controls, and the two ADHD groups did not differ on a wide range of output speed and most other comparisons. As Nigg et al. concluded, these findings support the relatedness of the two ADHD subtypes with respect to neuropsychological deficits. However, their findings suggest that measures of inhibitory control may help to differentiate subtypes.

Taken together, these results point only in a limited way to possible neuropsychological differences among ADHD subtypes, but it is clear that more research is needed. However, in part due to the decision to de-emphasize an inattentive subtype in the DSM-III-R, most of the ADHD literature in recent years has focused on what is now the combined type. Although the DSM-IV has recognized a predominantly inattentive subtype, and although children with the inattentive subtype appear behaviorally different than children with combined subtype, few studies as of yet have evaluated neuropsychological or cognitive differences between DSM-IV subtypes. Better evidence about the cognitive mechanisms underlying ADHD subtypes would clarify the theoretical validity of these subtypes (or the validity of the inattentive subtype as a distinct disorder) and would provide a framework for understanding the behavioral differences discussed above.

Theoretical Models

The range of measures utilized in the preceding studies underscores the need to better define and measure theoretically important cognitive mechanisms related to ADHD subtypes. Several neuropsychological theories about ADHD attempt to address such mechanisms in the combined type (Quay, 1988; Barkley, 1997; Sergeant, Oosterlaan, & van der Meere, 1999). A drawback to these theories for the purpose of the present discussion is that they address only in passing the predominantly inattentive subtype of ADHD. These theories are therefore briefly described before an alternative is presented for the inattentive subtype.

The deficient BIS model. Quay (1988) applied Gray's (1982) model of anxiety to explain disruptive behavior disorders in children. Gray posited the existence of a behavioral activation system (BAS) and a behavioral inhibition system (BIS), which relate to emotion. The BAS is activated by signs of immediate reward while the BIS is activated in response to signals of impending punishment and nonreward. According to Quay, ADHD-C results from a deficient BIS. Children who are less sensitive to signals indicating future punishment are more likely to act on impulse because they are less aware of negative consequence for their behavior. It is important to note that this claim is in question (Iaboni, Douglas, & Baker, 1995; for review see Nigg, 2001). Although it addresses poor motor inhibition, or impulsivity, the theory proposed by Quay does not account well for apparent deficits in attention in the combined type. Moreover, this theory explicitly is not applicable to the predominantly inattentive subtype of ADHD.

The cognitive-energetic model. Sergeant et al. (1999) applied Sternberg's (1969) and Kahneman's (1973) models of information processing and effort to develop a theory

of cognitive processing problems in children with ADHD. They noted that children with ADHD appear to have inhibitory deficits. However, they argued that the apparent disinhibition in these children is not the core cognitive mechanism in ADHD. Rather, they propose that process and state regulation factors influence processing efficiency, and that the disinhibition apparent in ADHD is modulated by these factors. State regulation factors include three energetic pools. Effort, the first pool, pertains to the energy needed to meet the demands of a particular task. Arousal, the second pool, is described as responding that is phasic and time-locked to stimulus processing. The third pool, activation, is characterized by tonic physiological readiness to respond. Disinhibition in ADHD depends on the process factors, which relate to task demands, and the state of the individual. Proponents of this model have concluded that inattention and cognitive inhibition are unaffected in ADHD combined type. Instead, they have argued, children with ADHD-C are unable to put forth enough effort to perform optimally. However, as they have relied mainly on selective attention paradigms (Sergeant et al.), it is doubtful that they have evaluated cognitive inhibition as it has been defined herein. Furthermore, that model does not address the inattentive subtype.

Executive behavioral inhibition. Barkley (1997) applied Bronowski's (1967) theory of delayed responding and Fuster's (1989) theory of prefrontal cortical functions to his model of ADHD – combined type. Like those discussed previously, Barkley's model emphasized a deficit in behavioral inhibition, but additionally provided a connection between behavioral inhibition and four executive functions. Executive functions as he defined them relate to the ability to maintain goal directed behavior as well as the ability to adjust behavior in response to context (Pennington & Ozonoff,

1996). Barkley asserted that nonverbal working memory, internalization of speech (verbal working memory), the regulation of affect, motivation, and arousal, and reconstitution (the capacity for analysis and synthesis) depend on efficient behavioral inhibition in order to develop and perform normally. Therefore deficient behavioral inhibition, the central deficit in ADHD according to Barkley's model, leads to secondary deficits in the executive functions mentioned above. These in turn result in marked problems with self-control and maintaining goal-directed behavior (Barkley, 1997). This model also explains the behavioral and apparent attentional deficits in ADHD combined type. However, like Quay (1988), Barkley asserted that the predominantly inattentive subtype of ADHD is a separate, dissimilar disorder. In contrast to the combined type of ADHD, where apparent inattention and distractibility presumably arise from primary impairments in behavioral inhibition, the predominantly inattentive subtype of ADHD may be directly characterized by inattention. However, the latter deficit in the inattentive type was not well described.

Summary. If the inattentive subtype of ADHD is related to the combined subtype, it follows that a more integrative theory of ADHD is needed. Conversely, if the predominantly inattentive form of ADHD is a different disorder unrelated to the other two subtypes, a supplemental theory is required that explains the dysfunction in cognitive mechanisms related to the inattentive subtype.

Cognitive Inhibition as an Alternative Theory

An inhibitory process that is potentially distinct from those discussed by Quay (1988), Barkley (1997), and Sergeant et al. (1999) concerns cognitive rather than behavioral inhibition. Unlike behavioral inhibition, which refers to control of motor activity, cognitive inhibition relates to control of mental processes and clearing of working memory (Hasher & Zacks, 1988; Harnishfeger, 1995; Nigg, 2000). Barkley (1997) and Quay (1988) address behavioral inhibition, but not cognitive inhibition as it is defined here (although Barkley, 1997, has used the term with a different definition). Making this distinction could allow for a clearer theory of different inhibitory deficits in ADHD subtypes.

From the perspective of a limited mental resources model (Hasher & Zacks, 1979), diverse cognitive processes must compete for a limited amount of mental resources. It follows that performance on cognitive tasks is likely to suffer when demands on mental resources are high. The limited resources view has been extended to emphasize the role of inhibition as it relates to working memory (Harnishfeger, 1995). Working memory can be thought of as a system of mental resources that allows for the manipulation of information. Because working memory space is limited, it is important that this space is protected to allow for the processing of task- or goal-relevant information.

Cognitive inhibition and efficient processing in development

It has been suggested that although children become more cognitively efficient throughout childhood, the amount of mental "resources" available during development is stable (Bjorklund, 1985). As children grow they become more efficient processors,

thereby freeing up mental resources to be used with other tasks (Case, Kurkland, & Goldberg, 1982). From this framework, the development of cognitive inhibition is fundamental to the development of efficient processing. Cognitive inhibition, defined as "the process of actively suppressing previously activated cognitive contents or cognitive processes" (Kipp, Pope, & Digby, 1997), is critical in allocating and conserving mental resources. As Dempster (1992) argued, the ability to inhibit, or to be resistant to interference, is a major factor in the cognitive development and in the decline of mental ability later in life. As children grow older they develop the ability to inhibit irrelevant information and they become more cognitively efficient. They become able to prevent extraneous information from reaching working memory, and to flush irrelevant information from working memory, thus freeing up mental resources for cognitive operations pertinent to the child's goal. Perhaps children with ADHD, particularly the predominantly inattentive type, appear unfocused, "inattentive," "spacey," and distractible because of inefficient cognitive inhibition processes that fail to effectively suppress irrelevant information from working memory. Still, many clinicians and researchers may suppose that the combined type of ADHD is also associated with a poor ability to control the contents of working memory.

It should be noted that some researchers have argued that the concept of limited mental resources is not necessary in explaining cognitive inhibition. Even if resources were not limited, processing efficiency would decrease with a lot of extraneous information to process. Children can be seen as becoming more efficient at inhibiting irrelevant information, and at preserving working memory, without invoking a limited mental resources construct. The purpose of inhibition in this case would be to make

processing more efficient by limiting the amount of information being processed simultaneously. The present paper is agnostic on this point. The concept of limited mental resources is not a main concern herein. What is most salient is the ability to suppress mental content, or cognitive inhibition. Indeed, the idea of cognitive inhibition stands with or without a limited mental resources construct. The limited mental resources construct is relevant, however, in that some researchers include the concept in theories and research relating to cognitive inhibition.

Directed forgetting as a methodology for evaluating cognitive inhibition

One method frequently used to evaluate cognitive inhibition is the directed forgetting task. This task has been used as a means of studying cognitive inhibition in children (Harnishfeger & Pope, 1996) and older adults (Zacks, Radvansky, & Hasher, 1996) as well as younger adults. In addition, directed forgetting tasks have been used to study people diagnosed with psychological or psychiatric disorders, including posttraumatic stress disorder (e.g. McNally, Metzger, Lasko, Clancy, & Pitman, 1998), acute stress disorder (Moulds & Bryant, 2002), and obsessive-compulsive disorder (Wilhelm, McNally, Baer, & Florin, 1996). At least three variations of directed forgetting tasks are in use, including item-by-item, blocked, and "only" cuing methods. Each of these methods includes "to be remembered" (TBR) and "to be forgotten" (TBF) words. TBR words are associated with a cue that indicates that they should be remembered; TBF words are associated with a cue indicating that they should be forgotten.

Item-by-item cued directed forgetting tasks. In item-by item cued tasks, participants are presented with a list of items either auditorally or visually. The "remember" and "forget" cues are usually presented immediately following the

presentation of each item. The cues can be presented in the same modality as the items (auditory or visual words) or they can be in the form of visual symbols that follow each item. There are other variations of cue presentation as well. Some researchers (e.g. Wilson & Kipp, 1998) have suggested that the directed forgetting effects produced by the item-by-item cuing method reflect a selective rehearsal mechanism rather than an inhibitory mechanism. However, as Zacks et al. (1996) point out, stopping the rehearsal of a TBF item could be inhibitory in nature.

"Only" cued directed forgetting tasks. A second variation in the cuing method used in directed forgetting tasks is the "only" cuing method. In tasks using this method, two blocks of items are presented to participants. These blocks are differentiated from each other in some way, often by using different colored backgrounds for each block. After both blocks are presented, participants are asked to recall all of the items from one of the blocks. The other block consists of TBF items. Participants tend to recall more TBR items in this "only" condition than they do in the control condition in which they have to recall both blocks (Bjork, 1972).

Blocked cued directed forgetting tasks. In the blocked cuing method, the list of words presented to participants is divided into two sets. After the first set, a cue or instruction is given to either remember or forget the set. Compared to the item-by-item cuing method, this method of cue presentation is preferred by some researchers (e.g. Harnishfeger & Pope, 1996; Wilson & Kipp, 1998) who argue that the directed forgetting effects produced are not explainable by selective rehearsal. When items are designated as TBF or TBR individually after each is presented, subjects can rehearse only the TBR items. Conversely, when a whole block of items is presented before it is designated as

TBF or TBR, subjects rehearse the items because they don't know whether or not they need to remember them.

Directed forgetting effects

The blocked-cuing method is perhaps the most commonly used method because it is relatively uninfluenced by selective rehearsal (repetition of TBR words; no repetition on TBF words). When asked to recall all items, adult participants typically recall fewer TBF items than TBR items, but recognize equal numbers of both (Wilson & Kipp, 1998) in blocked-cued designs. That participants are able to recognize TBF items is interpreted as evidence that the items are encoded, although they were inhibited during recall. However, Zacks et al. (1996, Experiment 2) reported poorer recognition of TBF than TBR items using a blocked-cuing procedure in older adults. Nevertheless, the difference between the number of TBR and TBF items recognized was much smaller than the difference between the number of TBR and TBF items recalled. They suggested that their findings concerning recognition differences might be attributable to procedural differences between their study and other studies that use this method. In many of the studies reported, one word list is used followed by recall and then recognition. In the study by Zacks et al. (1996), several word lists were used with recall after each list and a final test of recognition at the end. Further investigation is needed to determine if this pattern stands.

Directed forgetting in children

The directed forgetting paradigm has been used with children to evaluate the development of efficient cognitive inhibition. Harnishfeger & Pope (1996) demonstrated that cognitive inhibitory abilities develop throughout childhood. In the main study, they

tested first graders, third graders, fifth graders, and adults on lists of 20 words using a blocked-cuing design. They found that while adults seem to be able to effectively inhibit TBF items, this ability goes through developmental change in childhood. First grade children were unable to effectively inhibit TBF words from recall; thus there were no significant differences in the number of TBR versus TBF words recalled. Third graders exhibited some ability to adapt to forget cues, but their performance was much poorer than fifth graders, who inhibited almost as effectively as adults did. Recognition was consistently high and there were no significant recognition differences across age groups (Harnishfeger & Pope 1996).

Other studies have used directed forgetting tasks with children and found similar results (e.g. Bray, Justice, & Zahm, 1983; Posnansky, 1976). Bray et al. (1983) tested first, third, and fifth graders using blocked-cued directed forgetting methods and found that with each rise in grade level the children became more efficient at inhibiting TBF items. This indicates a more mature pattern of inhibition develops in children as they grow older during middle childhood. Similarly, Posnansky (1976, experiment 2), using an "only" cued directed forgetting procedure, found that seventh graders were more efficient inhibitors than third graders. These and other developmental directed forgetting studies have been reviewed in greater depth elsewhere (Wilson & Kipp, 1998). However, in summary they demonstrate that the ability to suppress mental content develops through early to middle childhood, making it a promising candidate for study in developmental psychopathology at this age period.

Cognitive inhibition and ADHD

As implied earlier, several considerations make cognitive inhibition of interest in relation to the inattentive and combined subtypes of ADHD. All of the major theoretical models of ADHD ignore the inattentive subtype (ADHD-PI), except in passing (Barkley, 1997; Quay, 1988). Furthermore, the inattention and distractibility evident in children with ADHD-PI could well be explained by a model of cognitive disinhibition. With respect to the combined type (ADHD-C), cognitive inhibition is also of interest because evidence of a deficit in cognitive inhibition would challenge the theoretical models that propose motor inhibition is impaired while cognitive inhibition should not be (eg. Barkley, 1997). Conversely, finding no evidence of a deficit in cognitive inhibition in the combined type would lend support to theories emphasizing motor inhibition. Such a finding might also differentiate the subtypes based on the type of inhibitory deficit present, if such a deficit is present in the inattentive subtype. It follows that more research is needed on inhibitory deficits in ADHD, particularly in relation to the subtypes. It is possible that a deficit in cognitive inhibition is the primary deficit in ADHD-PI, while children with ADHD-C have other inhibitory deficits, perhaps in behavioral or motor inhibition (Nigg 2000; 2001). In short, investigation of cognitive inhibitory processes in children with both ADHD subtypes may contribute to a clearer picture of the possible neurocognitive mechanisms associated with their differing but related symptoms.

ADHD and Directed Forgetting

Only one previous study has looked at children with ADHD using a directed forgetting procedure (Gaultney, Kipp, Weinstein, & McNeill, 1999). The participants for that study were a group of 29 ADHD children, diagnosed by a psychologist or medical

doctor, who were tested off of their medication. A control group of 29 children also participated. The authors did not indicate which version of the DSM was used for diagnosis, nor were ADHD subtypes specified. It is possible that most of the children had ADHD-C, considering that the authors described ADHD only in general terms as consisting of hyperactivity, inattention, and impulsivity. Participants from both groups were assigned to either the "remember" or "forget" condition in this between-groups design, so that both conditions had approximately half of the ADHD children and half of the control children. After the participants were presented the first set of items in a block-cued directed forgetting task, they were given instructions to either remember or forget the previously presented words. The second set was then presented. Participants were asked to recall all of the words presented and then were given a recognition test. There were no significant differences between ADHD and control children on their recall or recognition of the word list in either condition; the mean number of words recalled was similar in the two groups.

Although those results did not support the theory that children with the combined type of ADHD have cognitive inhibitory deficits, they underscore the need for studies of ADHD subtypes. In addition to the relatively small sample of ADHD children (for a between-subjects design), and their rather large age range (8 to 15 years), an adequate standardized procedure for diagnosing ADHD was not utilized. Unstandardized clinician diagnoses have well-known problems with reliability and validity (Hinshaw & Nigg, 1999). Further, subtypes were not addressed. However, Gaultney et al.'s (1999) results could be consistent with a model in which deficits in cognitive inhibition characterize the inattentive but not the combined subtype of ADHD. In this case, children with ADHD-C

would not be expected to exhibit deficits in cognitive inhibition on a directed forgetting task. Children with the predominantly inattentive ADHD subtype might still be expected to exhibit cognitive inhibitory deficits. In summary, the possible link between deficits in cognitive inhibition and the inattentive symptoms and subtype of ADHD might clarify differences or similarities in ADHD subtypes in one important arena of cognitive functioning.

Rationale for the Current Study

The proposed study evaluated cognitive inhibition in DSM-IV defined ADHD subtypes, one primary hypothesis was based on the idea that ADHD-C is related to motor inhibition problems while ADHD-PI is not (Barkley, 1997; Quay, 1988). Thus, one key hypothesis to be tested was that children with the inattentive subtype have different neuropsychological and cognitive deficits than do children with the combined type of ADHD. More specifically, it was hypothesized that children with predominantly inattentive symptoms have deficits in cognitive inhibition, which are related to their apparent inattention. Conversely, children with both inattentive and hyperactive/impulsive symptoms (combined type) were not expected to have cognitive inhibitory deficits if leading theories that emphasize motor control are correct (Barkley, 1997; Sergeant et al., 1999). Therefore, children with ADHD-PI, who were thought to have deficits in cognitive inhibition, were expected to perform poorly on directed forgetting tasks that tap into this type of inhibition compared to ADHD-C and control children. Of course, competing models could predict that both groups, or the ADHD-C group alone, should be impaired in their cognitive inhibitory ability (see Nigg, 2001). Therefore, an hypothesis based on a global disinhibition model of ADHD-C (motor and cognitive inhibition) was also included, as well as an hypothesis that the two subtypes would share a deficit in cognitive inhibition (a shared deficit or severity model of related subtypes).

Specific Hypotheses. A definition of the conditions that comprise the blocked-cued directed forgetting procedure used in the study is given in Appendix 1 (page 58). The procedure is further detailed in the Method section later. Because different models

make different predictions, competing hypotheses are included. One of the primary issues in the field is whether the two ADHD subtypes really are related or different disorders, with similar or distinct cognitive deficits (APA, 1980; 1994; Milich et al., 2001). The hypotheses were designed to clarify that issue. Hypothesis 1. Consistent with the primary model in this study, in which only the children with the inattentive subtype of ADHD (ADHD-PI) have deficits in cognitive inhibition, it was predicted that children with ADHD-PI, relative to controls and children with ADHD-C, would recall a greater number of Set B Comparison than Suppression items, indicating that the presentation of TBF items in the Suppression condition interfered with their ability to recall TBR items in that condition. In addition, recall of Set B Suppression items was not expected to differ from recall of No Suppression items, if TBF items interfered with recall of TBR items in the Suppression condition. Hypothesis 2. An alternative hypothesis was that the subtypes shared a deficit in cognitive inhibition. If so, the hypothesis would be that both subtypes would recall a greater number of Set B Comparison items and a roughly equal number of No Suppression items compared to suppression items. Hypothesis 3. A third hypothesis was that only the ADHD-C group would perform in a way that was suggestive of a deficit in cognitive inhibition, as described above. This would be consistent with a model of ADHD in which the combined type alone was characterized by executive function problems and concomitant inhibitory deficits, while children with the inattentive subtype experienced other deficits, perhaps in arousal. However, prior to tests of these hypotheses preliminary studies were undertaken to evaluate a repeated measures directed forgetting design.

Preliminary Studies

Study 1

The purpose of the first preliminary study was twofold. Its primary purpose was to evaluate the repeated measures design operationalized for the main study (prior studies usually used a between-group design). It was also intended to provide a means for testing and improving the procedures and materials to be used in the main study.

Participants. The participants (n=21) for this experiment were recruited from the undergraduate subject pool at Michigan State University and received course credit for their participation. One participant was dropped from the study due to difficulty with the English language, and one was dropped for not following directions. The mean age of the remaining n = 19 participants was 19.7 years, and all were female.

Materials. Booklets of line drawings of common objects were used in the study. Drawings were chosen rather than word lists to minimize the effect of reading ability on task performance, particularly because one would expect the ADHD groups to have more reading difficulties than the control group. These drawings were developed by Snodgrass and Vanderwart (1980) and were normed on both adults (Snodgrass & Vanderwart, 1980) and children (Berman, Friedman, Hamberger, & Snodgrass, 1989). 100 of the original 267 drawings were selected for this study based on their name agreement and familiarity. Each drawing was printed in black in the center of a sheet of unlined white paper. The size of each drawing varied according to the size of the object depicted (e.g. the elephant drawing was larger than the button drawing) based on the experimenter's judgement. These drawings were randomly arranged into ten groups of ten drawings. They were inserted in clear plastic sheet protectors and placed in binders to make the booklets. A

recognition booklet was also created. It consisted of 50 randomly arranged drawings, of which 20 were "remember" items, 5 were "forget" items, and 25 were distracter items.

Procedure. Each participant received the first three conditions listed in Appendix 1 (page 58), in addition to the final recognition test, in this block-cued experiment. The order of conditions varied (described below). Groups of 20 pictures were divided into two sets, A and B. The exception was the Comparison condition, which only contained 10 (Set B) items. Set A refers to the first 10 pictures for a particular condition. Set B included the second 10 pictures for a particular condition, as well as the 10 Comparison items. Comparisons were made across conditions within each set rather than across sets within conditions, to clarify inhibition effects. The conditions were as follows: (1) In the No Suppression condition, Set A items were presented and then participants were asked to remember them as well as Set B items, which were then presented. A recall test of all 20 drawings followed. (2) In the Suppression condition, participants were shown 10 Set A items but then told to forget them (TBF) because they were from the wrong set. They were instructed instead to remember the "right" Set B items (TBR) that were then presented. A recall test of the 10 TBR items followed. (3) In the baseline or Comparison condition, participants were shown Set B drawings with no direction to remember or forget them other than the general directions given prior to administering the task (See Appendix 1, p. 57). They were then given a recall test of these 10 items. A final recognition test was given in which participants were asked to recognize selected TBR and TBF items previously presented. The instructions used for this experiment are provided in Appendix 2 (page 58).

The sequence of conditions was varied by means of a Latin Squares approach, so that participants received the conditions in one of three different orders – (a) No Suppression, Suppression, Comparison; (b) Suppression, Comparison, No Suppression; (c) Comparison, No Suppression, Suppression. In addition, the drawing sets were rotated in a similar fashion so that each set of drawings appeared in each position within a condition and across conditions (and as distracter items in the recognition test). Considering the 10 different list orders and the 3 different condition orders, there were a total of 30 possible presentation arrangements to which participants could be assigned; each participant received a unique arrangement. The recognition test was the same for each participant, but the status of each word (remember, forget, or distracter) varied depending on the ordering of the sets across conditions.

The experimenter presented the drawings to the participant manually at the rate of approximately 1 every 3 seconds. Participants were to name each drawing out loud. Between conditions and before the recognition test, participants played a game of cards with the experimenter for about three minutes. This break was designed as a "memory flush" which was intended to clear the information from the preceding task from the participant's mind. The procedures for the first preliminary study were approved by the Michigan State University Internal Review Board for Protection of Human Subjects (UCRIHS, **IRB 96-7201**).

It was expected that fewer Set A Suppression items would be recalled compared to No Suppression items. It was further predicted that more Set B Suppression items would be recalled than Set B No Suppression items; the former was not expected to differ

from recall of Set B Comparison items. Together these findings would indicate minimal interference from TBF words in the recall of TBR words.

Results. The descriptive statistics for Study 1 are displayed in Table 1. Repeated measures Analyses of Variance (ANOVAs) were performed to evaluate the predictions. As will be recalled, ANOVAs focused on comparing within set and across condition. First, for Set A, as predicted more No Suppression than Suppression items were recalled ($F_{(1, 18)} = 60.19$, $p < 0.001$, $\eta^2 = 0.77$)[1]. For set B, also as predicted, a greater number of Suppression than No Suppression items were recalled ($F_{(1, 18)} = 7.41$, $p = 0.014$, $\eta^2 = 0.29$), while recall of Set B Suppression and Comparison items did not differ ($p = 0.11$, $\eta^2 = 0.14$). As expected, recognition of TBR and TBF items did not differ ($p = 0.44$, $\eta^2 = 0.02$), but both were greater than recognition of distracter items ($F_{(1, 18)} = 2190.80$, $p < .01$, $\eta^2 = 0.99$ and (1, 18) = 629.00, $p < 0.001$, $\eta^2 = 0.97$, respectively).

Table 1: Means and Standard Deviations in Proportions for Recall and Recognition of Picture Names for Study 1.

		Recall			Recognition		
Condition		No Suppression	Suppression	Comparison	TBR	TBF	Lures
Mean Recall (SD)	Set A	.40 (.14)	.01 (.01)	--	--	--	--
	Set B	.46 (.16)	.58 (.17)	.65 (.14)	--	--	--
	Total	--	--	--	.92 (.05)	.91 (.15)	.04 (.05)

Note n = 19; TBR = "Remember," TBF = "Forget."

[1] η^2 is reported as an estimate of effect size commonly used in ANOVA.

Discussion. Overall, these data indicate that the adults were able to inhibit TBF items successfully. This is most clearly supported by the fact that there was no significant interference from the presentation of TBF items with recall of TBR items as evidenced by the pattern of Set B results. The significant difference in recall between Set A conditions may have been the result of cognitive inhibition, however it may have been due to other operations such as speech suppression, a conscious decision to withhold recall of retrieved TBR items. As described below, some participants indicated that they were able to remember TBF items as well but did not mention them during recall. Since items were not suppressed, but were remember as TBF items, this was not an example of cognitive inhibition.

Preliminary Studies 2 and 3

The purpose of the second and third preliminary studies was to test the repeated measures design in children. In this experiment, the repeated measures design was used with two samples of 4th graders to evaluate whether the expected directed forgetting effects would occur in this age group using this type of design. The materials and procedure used in the first study were also used with the children.

A secondary goal was to pilot a new test condition. As was noted, during recall in the "suppression" condition, some of the participants from the first preliminary study indicated that they remembered additional words, but knew they were from the TBF set. As noted above, this may indicate that processes other than cognitive inhibition (eg. speech suppression) partially accounted for the lower recall of TBF words. Therefore, an additional purpose of these studies was to find evidence that the difference between TBF

and TBR words recalled in the "suppression" condition is actually due to cognitive inhibition. To do this, a fourth condition, described below, was added to this study.

Participants. The participants in these experiments (Study 2, N = 19; Study 3; N = 15) were students in two different 4th grade classes recruited from a local school district. They were compensated for their participation with a small toy and the school was compensated with supplies. Parents provided written informed consent and children provided assent.

Materials and procedure. The procedures used in preliminary Studies 2 and 3 were approved by the UCRIHS (**IRB 96-601**). The booklets and procedure described in Study 1 were also used in these subsequent studies. However, a fourth condition was added. In this condition, called the Suppression-Recall All condition, participants were instructed to forget Set A and remember Set B items. However, recall of all 20 words was then requested. This condition was always presented last, but before the recognition test, so as to avoid any effect that this misrepresentation might have had on performance in the other conditions. Children were debriefed after the experiment.

In part due to the addition of this condition, the instructions were updated for preliminary Study 2 and no longer required the experimenter to "accidentally" present the wrong set of pictures. A more straightforward approach was taken in which participants were told in advance that they might be told to forget certain sets of pictures. The revised instructions are presented in Appendix 3 (pages 59-60). Due to the addition of the Suppression-Recall All condition, the books also needed updating. An additional 20 pictures from Snodgrass and Vanderwart (1980) were included for this condition. It was noted that some children had difficulty naming a number of the additional pictures in

Study 2, so these pictures were replaced with other pictures from Snodgrass and Vanderwart (1980) for Study 3.

Study 2 Results. The descriptive statistics for Study 2 are displayed in Table 2. Repeated measures ANOVAs were performed to evaluate predictions made for Sets A and B. For Set A, a greater number of No Suppression than Suppression items were recalled, however this difference was just shy of significance ($p = 0.05$, $\eta^2 = 0.20$). Recall of No Suppression and Suppression-Recall items did not differ ($p = 0.13$, $\eta^2 = 0.12$). This may suggest that speech suppression rather than cognitive inhibition was operating, because participants were clearly able to recall more Set A (TBF) items when they were asked to. However recall in both conditions was so low that it may have been the result of an idiosyncrasy of this particular sample.

Table 2: Means and Standard Deviations in Proportions for Recall and Recognition of Picture Names in Study 2.

		Recall				Recognition		
Condition		No Suppression	Suppression	Comparison	Suppression Recall All	TBR	TBF	Lures
Mean Recall (SD)	Set A	.33 (.21)	.19 (.17)	--	.24 (.08)	--	--	--
	Set B	.42 (.18)	.50 (.17)	.57 (.15)	.42 (.15)	--	--	--
	Total	--	--	--	--	.91 (.08)	.90 (.10)	.16 (.02)

Note n = 19; TBR = "Remember," TBF = "Forget."

For Set B, recall of Suppression items did not differ from No Suppression ($p=0.15$, $\eta^2 = 0.11$) or Comparison ($p = 0.15$, $\eta^2 = 0.11$) items. This was only partially consistent with the pattern of recall of Set B items predicted if cognitive inhibition its occurring. That is, recall of Suppression items was expected to be greater than recall of

No Suppression items. Overall, the data suggest that this 4th grade sample had somewhat of an ability to inhibit TBF items but were less efficient than adults. This is consistent with the literature of the development of cognitive inhibition in children (Harnishfeger, 1995; Harnishfeger & Pope, 1996), however a third preliminary study was run on a different fourth grade sample from a different local elementary school to determine if these findings would hold.

Study 3 Results. The descriptive statistics for Study 3 are displayed in Table 3. Repeated measures ANOVAs were performed to evaluate predictions made for Sets A and B. For Set A, a greater number of No Suppression than Suppression items were recalled ($F_{(1, 14)} = 5.03$, $p = 0.04$, $\eta^2 = 0.26$). Recall of No Suppression and Suppression-Recall items did not differ ($p = 0.81$, $\eta^2 = 0.00$). For Set B, recall of Suppression items did not differ from No Suppression ($p=0.19$, $\eta^2 = 0.12$) or Comparison ($p = 0.08$, $\eta^2 = 0.20$) items. Like Study 2, this was only partially consistent with the pattern of recall of Set B items predicted if cognitive inhibition its occurring. That is, recall of Suppression items was expected to be greater than recall of No Suppression items.

Table 3: Means and Standard Deviations in Proportions for Recall and Recognition of Picture Names for Study 3.

		Recall				Recognition		
Condition		No Suppression	Suppression	Comparison	Suppression Recall All	TBR	TBF	Lures
Mean Recall (SD)	Set A	.27 (.14)	.14 (.17)	--	.26 (.14)	--	--	--
	Set B	.37 (.14)	.43 (.01)	.53 (.17)	.38 (.12)	--	--	--
	Total	--	--	--	--	.84 (.08)	.83 (.13)	.02 (.03)

Note n = 15; TBR = "Remember," TBF = "Forget."

Discussion. These data suggest that although both groups of the 4th grade children had some ability to inhibit TBF items, there was still interference from these items in the recall of TBR words. This was demonstrated by the recall of Set B Suppression items relative to the recall of No Suppression and Comparison items. If there was no interference (perfect suppression), recall of Set B Suppression items would have been greater than recall of No Suppression items, but this difference was not significant in either 4th grade sample. However, recall was not significantly greater for Comparison than Suppression items in either sample, indicating some cognitive inhibition occurred. That is, the presentation of Set A Suppression items did not significantly lower recall of Set B Suppression items. Although recall of Set A No Suppression items was greater than recall of Set A Suppression items, when children were instructed to recall TBF items in the Suppression-Recall All condition this significant difference disappeared. However, recall was so low in the No Suppression condition, particularly in Study 3, that caution must be used when interpreting these data. Overall there was some evidence based on Set B performance that children were inhibiting TBF words, but that they were not as efficient as the adults. These results are consistent with other studies using directed forgetting tasks with children. For example, Harnishfeger and Pope (1996) found that third-graders show limited inhibitory ability, but that fifth-graders inhibit almost as well as adults. The present samples of fourth-graders fell in the middle of these two groups.

"Main Study" or Study 4

Method

Participants. 75 children (n = 27 control, n = 33 ADHD-C, and n = 15 ADHD-PI) from 3rd through 5th grade in the Lansing area participated in this experiment. Most children were recruited to participate in a larger ongoing study, directed by Dr. Nigg at MSU, of which this study is a part. Thirty-two children were recruited through a newspaper advertisement for this specific study. The remaining children were recruited in a mailing to the parents of all third- through fifth-grade students in the Lansing school district or through advertisements placed in local newspapers about the larger MSU study. All who expressed interest, regardless of the method of recruitment, entered a multi-stage screening process.

An overview of the recruitment procedures follows. First, the child and his or her family needed to pass pre-screen qualifications (evaluated by telephone). These pre-screen qualifications included a willingness to keep the child off of short acting psychostimulant medication for 24 hours, and long acting psychostimulant medication for 48 hours prior to the visit, and a stipulation that English was the first language of the parents and children. Children taking longer-acting non-stimulant psychotropic medications (e.g. Cylert, Klonadine, or anti-depressants) were excluded. Also excluded were children with neurological impairments or other major psychiatric or medical conditions as reported by parents at pre-screen.

Parents and teachers then completed pre-screening questionnaires. These included the home and school versions respectively of the ADHD Rating Scale (DuPaul, Power, Anastopoulos, & Reid, 1998), the Parent and Teacher Behavior Assessment System for

Children (BASC; Reynolds & Kamphaus, 1992), and the Parent or Teacher Conners Rating Scale-Revised-Short Form (CRS-R-SF; Conners, 1997). These are all established, widely used rating scales with excellent reliability and normative bases.

If the child exceeded empirically established screen-in cut-offs on these questionnaires for possible ADHD (above 80th percentile on at least one normed parent rating scale and at least 90th percentile on at least one teacher rating scale), or if they were below cut-offs to be eligible for the control group (less than 80th percentile on all parent and teacher rating scales), then the mother completed the Diagnostic Interview Schedule for Children (DISC-IV; Shaffer, Fisher, & Lucas, 1997), to evaluate whether formal DSM-IV criteria for ADHD combined or inattentive type were met.[2]

Children with an estimated WISC-III FSIQ score below 75 were also excluded from the study. Although some children completed a full WISC-III while others completed a 5-subtest short form of the WISC-III, an estimated FSIQ based on the five subtests (Picture Completion, Information, Similarities, Block Design, Vocabulary) was used for all children for consistency purposes. This short form of the WISC-III provides a reliable and valid estimate of FSIQ (Sattler, 1992).

Final ADHD subtype diagnostic assignments for the study were made using the DISC-IV supplemented by an "or" algorithm. The "or" algorithm was implemented based on the validity data from the DSM-IV field trials (Lahey et al., 1994). Symptoms reported by the parents on the DISC-IV were summed with teacher reported symptoms from the ADHD Rating Scale for children who met duration, impairment, cross-situational, and

[2] To this end, there were two routes into the study. Some mothers completed the DISC-IV during an in-person full screening visit while other mothers completed relevant portions of the interview in a phone screen to determine eligibility for the study.

onset criteria.[3] In addition, children who had four or fewer hyperactive and four or fewer inattentive symptoms using the "or" algorithm, and who did not have other major mental or physical health problems were invited to participate as a part of the control group. Children with 5 symptoms of ADHD by the "or" algorithm were excluded from all groups. Children with ADHD-PH were not included in this study. Control group children could have oppositional defiant disorder or other disorders except conduct disorder, however most did not (described below).

Materials and procedure. The booklets and procedure described in Study 2 were used for the current study as well. A 3(group) x 3(condition) ANOVA was performed to evaluate between-subjects and within-subjects factors for Set A items. The three groups were ADHD-PI, ADHD-C, and control; the conditions were No Suppression, Suppression, and Suppression-Recall All. A 3(group) x 4(condition) ANOVA was performed to evaluate between-subjects and within-subjects factors for Set B items. The three groups again were ADHD-PI, ADHD-C, and control; the conditions were the same as the prior analysis with the addition of the Comparison condition.

Power and effect size. Eta square (η^2) is reported as a measure of effect size. It is interpreted in a manner similar to r^2 (Cohen & Cohen, 1983). Cohen and Cohen (1983) suggested that when $\eta^2 = 0.15$ effects are large, and when $\eta^2 = 0.06$ effects are medium in magnitude. Cohen and Cohen recommend using the f-statistic (which is ½ of d) as an effect size parameter in power analysis for ANOVA. If the medium to large effect size

[3] This procedure maximizes the validity of diagnostic assignment (Lahey et al. 1994) but increases the potential for different results versus less valid but often used methods that rely only on parent report. A total of n = 13 children needed teacher symptoms for their diagnostic subgroup classification. Eight children moved from the ADHD-PI to the ADHD-C group, one child moved from the ADHD-PH to the ADHD-C group, one child who had no diagnosis was

(approximately $\eta^2 = 0.12$ or $f = 0.32$) typically found in the ADHD neuropsychological literature (Pennington & Ozonoff, 1996) are assumed in the present study, between group effects had the following power. Power was 0.80 for comparing the two ADHD groups (pooled) versus the control group. Power was approximately 0.70 for ADHD-C versus control comparison at $f = 0.32$ ($\eta^2 = 0.12$); power was 0.80 to detect $f = 0.35$ ($\eta^2 = 0.11$). For ADHD-PI versus control comparisons, power was 0.55 at $f = 0.32$ ($\eta^2 = 0.12$); power was 0.80 to detect $f = 0.43$ ($\eta^2 = 0.16$; large effect). For comparisons between the two ADHD groups, power was 0.60 at $f = 0.32$ ($\eta^2 = 0.12$); power was 0.80 to detect $f = 0.40$ ($\eta^2 = 0.14$). For comparisons between repeated measures task conditions (collapsed across groups, repeated measures effect sizes were used based on effect sizes found in the three preliminary studies. Power was greater than 0.95 at $f = 0.42$ ($\eta^2 = 0.15$); and power was .80 to detect $f = 0.23$ ($\eta^2 = 0.05$; small effect).

Primary hypotheses relied on group by condition interactions. Power was also estimated therefore for key group x condition interactions using the repeated measures design. When comparing the two ADHD groups pooled versus controls over two conditions, power was 0.96 to detect an interaction at $f = 0.32$ ($\eta^2 = 0.12$). When groups were ADHD-C, ADHD-PI, and control over two conditions, power to detect the interaction was 0.93 at $f = 0.32$ ($\eta^2 = 0.12$). For 2 x 2 interactions (group by condition), power was 0.92 for the ADHD-C versus control groups over two conditions, 0.82 for the ADHD-PI and control groups over two conditions, and 0.87 for the ADHD-C and ADHD-PI groups over two conditions at $f = 0.32$ ($\eta^2 = 0.12$). For Set A, power exceeded 0.95 for condition main effects and for the within-subjects omnibus test. For Set B, power

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moved to the ADHD-C group, and three children who had no diagnosis were moved to the ADHD-PI group due to use of the "or" algorithm versus the DISC-IV alone.

again exceeded 0.95 for condition main effects and for the omnibus test at $f = 0.32$ ($\eta^2 = 0.12$).

Data analysis and specific statistical predictions and tests. The expected results for the three hypotheses were as follows:

1. Cognitive inhibition deficit only in the inattentive group. If Hypothesis 1 is correct, then a group x condition interaction was predicted for the Set A comparison, such that differences in recall among conditions (No Suppression, Suppression, and Suppression-Recall All) would be greater for the control and ADHD-C groups than the ADHD-PI group. A group x condition interaction was also predicted for Set B items. Recall of items in the Suppression and Suppression-Recall All conditions was expected to be (1) significantly less then recall of items in the Comparison condition and (2) comparable to recall of items in the No Suppression condition for the ADHD-PI group, a demonstration of impaired performance on this task. For the control and ADHD-C groups, recall of items in the Suppression and Suppression-Recall All' conditions was expected to be (1) comparable to recall of items in the Comparison condition and (2) significantly greater than recall of No Suppression items.
2. Deficit in both ADHD groups. If Hypothesis 2 was correct, then condition x group interactions were again expected, in this case with the ADHD-C group performing like the ADHD-PI rather then the control group as described in Hypothesis 1.
3. Deficit only in the ADHD-C group. If Hypothesis 3 was accurate, that only the ADHD-C children have cognitive inhibitory deficits, then the two condition x

group interactions were again expected, with the pattern of performance for the ADHD groups switched relative to the predictions made in hypothesis 1.

Study 3 Results

Sample demographic characteristics for Study 3 are displayed in Table 4.

Table 4: Demographics

Dependent Measure	Control	ADHD-C	ADHD-PI	Significance (p)
N	27	33	15	
Age	120.5 (10.2)	117.3 (10.2	122.8 (16.2)	ns; p = .28
% Male	51.9%	78.8%	53.3%	ns; p = .06
Ethnicity (% Caucasian)	80.8%	64.5%	80.0%	ns; p = .37
% ODD	3.7%	42.4%	6.7%	p<.001 (A,C)
% CD	0%	9.1%	6.7%	ns; p = .34
Full Scale IQ	108.4 (16.3)	104.1 (15.8)	102.5 (15.9)	ns; p = .45
Word Attack	103.0 (13.2)	101.8 (17.2)	99.6 (10.8)	ns; p = .78
WIAT Reading	105.1 (10.4)	100.3 (19.1)	101.6 (12.1)	ns; p = .49
DSM-IV Hyperactive Sx	0.9 (1.3)	8.28.2 (1.1)	2.1 (1.9)	p<.001 (A,C); p<.05 (B)
DSM-IV Inattentive Sx	1.1 (1.5)	8.7 (0.7)	8.3 (0.8)	p<.001 (A,B)
BASC Hyperactivity (T)	41.6 (7.4)	71.7 (17.2)	47.5 (9.7)	p <.001 (A,C)
BASC Attention Problems (T)	44.0 (6.9)	69.0 (8.4)	70.9 (6.7)	p <.001 (A,B)
BASC Conduct Problems (T)	42.4 (7.6)	63.5 (16.3)	55.4 (16.9)	p<.001 (A,B)
BASC Aggression (T)	44.1 (5.7)	60.9 (16.1)	53.9 (9.8)	p<.001 (A); p<.05 (B)
BASC Anxiety (T)	46.6 (8.5)	52.3 (13.8)	53.7 (8.1)	ns; p = .07
BASC Depression (T)	44.7 (8.1)	63.0 (17.1)	57.7 (11.3)	p<.001 (A); p<.01 (B)
Conner's ADHD (T)	46.2 (5.4)	71.5 (9.5)	(70.6 (9.0)	p<.001 (A,B)
Conner's Cognitive Problems (T)	46.7 (5.7)	71.9 (10.3)	72.0 (8.7)	p<.001 (A,B)
Conners Hyperactivity (T)	46.9 (3.6)	72.8 (11.8)	57.3 (15.4)	p<.001 (A,C); p<.05 (B)
Conners Oppositional (T)	48.2 (7.9)	64.0 (13.8)	61.4 (12.9)	p<.001 (A); p<.01 (B)

Note: ADHD-C = attention deficit hyperactivity disorder combined type; ADHD-PI = ADHD inattentive type; ODD = oppositional defiant disorder; CD = conduct disorder; BASC = Behavioral Assessment System for Children; Conners = Conners ADHD Rating Scale. WIAT = Weschler Individual Achievement Test; ns = not significant. DSM-IV symptoms denote parent Diagnostic Interview Schedule for Children plus teacher endorsement ("or" algorithm). Behavioral ratings denote maternal T scores. A = Control vs. ADHD-C; B = Control vs. ADHD-PI; C = ADHD-C vs. ADHD-PI.

As shown in Table 4, groups did not differ in age, gender composition, ethnicity, IQ, or reading scores. The ADHD-C group had a greater proportion of children with conduct disorder as than did the other two groups. Behavioral ratings were consistent with what is found in the literature on ADHD subtypes.

Descriptive statistics for the directed forgetting task are displayed in Table 5.

Table 5. Means and Standard Deviations in Proportions for Recall of Picture Names by Group.

		Recall				Recognition		
		No Suppression	Suppression	Comparison	Suppression Recall All	TBR	TBF	Lures
Set A	Control	.36 (.17)	.17 (.15)	--	.18 (.15)	--	--	--
	ADHD-C	.32 (.18)	.13 (.15)	--	.19 (.16)	--	--	--
	ADHD-PI	.38 (.17)	.11 (.13)	--	.15 (.12)	--	--	--
	Total	.34 (.17)	.14 (.15)	--	.18 (.15)	--	--	--
Set B	Control	.38 (.14)	.40 (.18)	.52 (.16)	.33 (.15)	--	--	--
	ADHD-C	.37 (.17)	.38 (.19)	.50 (.16)	.33 (.18)	--	--	--
	ADHD-PI	.40 (.14)	.43 (.18)	.50 (.17)	.29 (.16)	--	--	--
	Total	.38 (.15)	.40 (.18)	.50 (.16)	.33 (.17)	--	--	--
Total	Control	--	--	--	--	.89 (.10)	.88 (.10)	.02 (.03)
	ADHD-C	--	--	--	--	.91 (.08)	.86 (.12)	.03 (.04)
	ADHD-PI	--	--	--	--	.93 (.06)	.90 (.12)	.04 (.05)
	Total	--	--	--	--	.91 (.09)	.88 (.11)	.03 (.04)

Because between-subjects designs are more commonly used with children in the directed forgetting literature, it was important to evaluate whether this tasked worked as expected with the control group. To this end, a repeated measures ANOVA was run for

Set A items for the control group. A main effect was found ($F_{(2, 52)} = 14.47$; $p < 0.001$, $\eta^2 = 0.36$), with planned comparisons revealing that recall was higher for the No Suppression items than the Suppression ($F_{(1, 26)} = 19.75$, $p < 0.001$, $\eta^2 = 0.43$) and Suppression-Recall All ($F_{(1, 26)} = 21.21$ $p < 0.001$, $\eta^2 = 0.45$) items. This supports the assumption that the task worked for the control group, in that recall of TBF items was lower than recall of TBR items, even when recall of TBF items was requested in the Suppression-Recall All condition.

A second repeated measures ANOVA was performed for Set B items for the control group. The main effect was significant ($F_{(3, 78)} = 8.32$, $p < 0.001$, $\eta^2 = 0.24$) with planned comparisons revealing recall of Suppression items was lower than recall of Comparison items ($F_{(1, 26)} = 11.20$, $p = 0.003$, $\eta^2 = 0.30$), but recall of Suppression items did not differ significantly from recall of No Suppression items ($p = 0.767$, $\eta^2 = 0.01$). The pattern of lower recall in the Suppression than Comparison condition and equivalent recall in the Suppression and No Suppression conditions indicates that there was interference from TBF items in recall of TBR items, but this is not unexpected in children of this age group. Moreover, as Table 4 illustrates, recall of Set B Suppression items was slightly higher than Set B No Suppression items, indicating a possible trend toward the predicted baseline inhibition effect. Because children are expected to be less efficient inhibitors than adults, and because there was room for a finding of group effects, the data were analyzed to test the hypotheses.

A 3 (group) x 3 (condition) repeated measures ANOVA was performed for Set A items. The group x condition interaction was not significant ($p = 0.42$, $\eta^2 = 0.03$), nor was the main effect of group ($p = 0.67$, $\eta^2 = 0.01$). A significant main effect of condition was

found ($F_{(2, 144)} = 39.16$, $p < 0.001$, $\eta^2 = 0.35$). Pairwise comparisons of each condition revealed that recall of Set A items was greater in the No Suppression condition than in the suppression condition ($F_{(1,72)} = 72.32$, $p < 0.001$, $\eta^2 = 0.50$) and the suppression-recall all condition ($F_{(1,72)} = 41.31$, $p < 0.001$, $\eta^2 = 0.37$). Effects supported suppression effects overall, however effects were not consistent with any of the hypotheses; neither of the ADHD groups demonstrated impaired performance relative to controls.

A 3 (group) x 4 (condition) repeated measures ANOVA was performed for Set B items. Neither the group x condition interaction nor the group main effect were significant ($p = 0.87$, $\eta^2 = 0.01$ and $p = 0.88$, $\eta^2 = 0.0$, respectively). A significant main effect of condition was found ($F_{(3, 216)} = 16.65$, $p < 0.001$, $\eta^2 = 0.19$). Planned comparisons revealed that recall of Set B items was greater in the Comparison condition than in the Suppression condition ($F_{(1,72)} = 11.93$, $p = 0.001$, $\eta^2 = 0.142$). Recall of Set B items in the Suppression and No Suppression conditions did not differ significantly ($p = 0.44$, $\eta^2 = 0.01$). This indicates that interference from TBF items lowered recall of TBR items, however this is expected in children. These results were not consistent with any of the ADHD-related hypotheses in that neither of the ADHD groups performed differently than controls. The pattern of results suggests that the children were not as efficient at inhibiting as would be expected from adults, but were able to inhibit TBF items to a degree consistent with their age.

To evaluate effects of the order of presentation of the three conditions on recall, a 3 (condition) x 3 (order) repeated measures ANOVA was performed for Set A items. The interaction was not significant ($F_{(4, 144)} = 0.52$, $p = 0.72$, $\eta^2 = 0.01$), suggesting that the Set A analysis was valid. A 4 (condition) x 3 (order) repeated measures ANOVA was

performed for Set B items for the same purpose. The order of condition presentation significantly affected recall ($F_{(6, 216)} = 3.64$, $p = 0.002$, $\eta^2 = 0.09$), suggesting that analysis of Set B items was not valid.

As a result, Set B data were re-analyzed in a between-subjects fashion, with only the conditions presented first included, despite the small resultant N. Because the Suppression-Recall All condition was always presented fourth it was not included in the order analyses. The descriptive statistics for initial presentations of each condition by group are displayed in Table 6. The number of subjects per cell and descriptive statistics

Table 6. Means and Standard Deviations in Proportions for Recall of Picture Names by Group when Condition Occurred First.

		No Suppression	Suppression	Comparison
Set A	Control	.44 (.16)	.19 (.15)	--
	ADHD-C	.32 (.15)	.13 (.16)	--
	ADHD-PI	.35 (.17)	.14 (.09)	--
	Total	.37 (.16)	.15 (.14)	--
Set B	Control	.35 (.14)	.39 (.18)	.47 (.19)
	ADHD-C	.35 (.17)	.42 (.09)	.41 (.14)
	ADHD-PI	.53 (.01)	.26 (.15)	.48 (.13)
	Total	.38 (.16)	.38 (.15)	.45 (.15)

for the conditions as a function of their order of presentation are displayed in Appendix 4 (page 61). A 3 (group) x 3 (condition) ANOVA was performed for Set B items to test the hypotheses outlined above. The group x condition interaction was not significant ($F_{(4, 66)} = 0.48$, $p = 0.75$, $\eta^2 = 0.03$), nor was the main effect of group ($F_{(2, 66)} = 2.03$, $p = 1.4$, $\eta^2 = 0.14$). The main effect of condition was significant ($F_{(2, 66)} = 8.02$, $p = 0.001$, $\eta^2 = 0.20$). Planned comparisons again revealed that recall of Set B items was greater in the

Comparison than in the Suppression condition ($p = 0.015$). Recall did not differ significantly between the No Suppression and Suppression conditions ($p = 0.142$), although Suppression condition recall was always greater than No Suppression condition recall. This difference, although insignificant, suggests that inhibition was occurring.

These data provide evidence that children were able to inhibit TBF items in that there was a tendency for children from all groups to recall more Set B Suppression than No Suppression items. However, the greater recall of Set B Comparison than Suppression supports the notion that children were not able to inhibit TBF items as efficiently as adults. Nonetheless, there were no group differences in recall. The data did not support any of the hypotheses of cognitive inhibitory deficits in ADHD.

Discussion

This study evaluated cognitive inhibition in children with two ADHD subtypes and a control group using a directed forgetting paradigm. Prior research has evaluated measures of what is thought to be behavioral or motor inhibition, usually in the combined ADHD subtype. The inattentive subtype has largely been ignored, or has been evaluated based on theories that attempt to explain deficits in the combined subtype but do not account well for the inattentive subtype. The fourth study herein examined cognitive inhibition in ADHD subtypes. One reason this topic is important is that there is a growing need to evaluate the validity of the inattentive subtype. Therefore, the present study aimed at adding to the literature on possible cognitive vulnerability in the inattentive subtype, as well as evaluating whether a deficit in cognitive inhibition distinguishes ADHD subtypes, or whether they do not differ on the presence or absence of such a deficit.

Only one prior study investigated cognitive inhibitory deficits as defined herein in ADHD (Gaultney et al., 1999). That study also used a directed forgetting procedure, but did not take ADHD subtype into account. A strength of the present study was the careful multi-stage diagnostic process used for assignment to diagnostic groups. Gaultney et al. relied on prior diagnosis by a physician to assign children to the ADHD group, a method that can be unreliable. The present studies also used a within subjects design with the hopes of increasing the power to find group differences.

In Study 1, the repeated measures directed forgetting procedure was used with college students who performed as expected for adults with intact cognitive inhibitory abilities. In Studies 2 and 3 the directed forgetting procedures were used with 4th graders,

yielding less clear-cut results. Consistent with the literature on the development of such inhibitory abilities (Dempster, 1992; Kipp et al., 1997; Wilson & Kipp, 1998), 4th graders demonstrated some ability to suppress information from working memory, however they were not as efficient as adults.

It was evident in all studies that the directed forgetting performance of normal 4th grade children was not as effective as that of adults, suggesting that these children were probably at what might be considered a transitional point in their development of the suppression mechanism probed by this task. This idea that the relevant ability was partially developed is suggested by their relatively efficient inhibitory ability based on Set A performance despite their vulnerability to interference in Set B. Nonetheless, there still appeared to be room for group differences in performance. In the present main study, no differences were found among the ADHD-C, ADHD-PI, and control groups on the directed forgetting task, and no group x condition interactions were significant. All three groups appeared to be transitional to a similar degree. The pattern of results did not seem to support the main or alternative hypotheses of the main study.

Before analyzing group differences for the main study, data for the control group were analyzed. These data led to the same conclusion spelled out above. That is, consistent with their age, children exhibited some ability to suppress information. Their ability to suppress was not as efficient as would have been expected for adults yet there was the possibility that the ADHD groups would perform more poorly than controls. To the contrary, no group differences were found. This null result could mean that (a) there are no ADHD deficits in cognitive suppression or (b) ADHD deficits in cognitive suppression were not found due to the transitional developmental stage of the children

studied, however in more cognitively developed children and adults such ADHD deficits might emerge.

The above effects were fairly clear for SET A items, for which the task operated as intended. However, examining of order effects revealed that the order of condition presentation (i.e. whether a particular condition appeared first, second, or third in the rotation) affected recall of SET B items. This order effect was also consistent with the examiners' qualitative behavioral observations when administering the directed forgetting task. With each successive condition, regardless of the order of presentation, performance seemed to drop in that children seemed to recall fewer TBR items. Furthermore, children seemed to make more intrusions from prior conditions toward the end of the task. Set B data were re-analyzed using only data for conditions administered first, with no change in conclusions. Although power for that secondary comparison was quite low, group means were very similar. The data for all three groups were closer to the pattern expected of relatively efficient inhibitors of cognitive content. Thus efforts to address problems with task order effects also failed to provide evidence that children with either subtype of ADHD have a deficit in cognitive inhibition.

Limitations

The number of conditions in this experiment, or the fact that they were presented successively with only a short break in between, caused significant interference for children of this age group. Prior research with children generally used a between subjects design, which often has the drawback of the low power because clinically diagnosed children are costly and time consuming to recruit, so samples are often small. Therefore a repeated measures design, demonstrated to work in adults in prior research (e.g. Zacks,

Radvansky, & Hasher, 1996) and in Study 1, was chosen for the current study. To be thorough, four different conditions were included to reduce the likelihood that findings were due to selective rehearsal, speech suppression, or a different process other than cognitive inhibition. In doing this, however, it appears that the task became difficult for the children. Examiners also noted that children frequently complained about having to do so many conditions. Nevertheless, children still seemed to perform at their expected developmental level.

Conclusions

As mentioned above, these children appeared to be at a transition point in development, demonstrated by their discrepant performance on Set A versus Set B. This made drawing conclusions from the data more difficult because the pattern of results expected of efficient inhibitors was not present. Not only was performance weaker for Set B, but order effects were also significant for Set B, indicating that children performed differently on the conditions depending on their order of presentation. Therefore, in addition to interference from Set A items, children also struggled with interference from prior conditions. When analyzing only those conditions that occurred first for each child, the pattern of results was closer to what would be expected with relatively efficient inhibition, however sample sizes were small for these comparisons. Nonetheless, no group effects were found and the data did not suggest even a trend in the direction of hypothesized ADHD deficits.

Results of the current study are consistent with the limited prior research on directed forgetting in ADHD (Gaultney et al., 1999). No deficit has been demonstrated in either subtype of ADHD on directed forgetting tasks. This suggests that cognitive

inhibition is not a core deficit in either ADHD subtype, at least at this developmental level. However, due to the limitations of both studies it is important to investigate this possibility further with clearly defined subtypes, a simpler design, and larger sample of older children. It is possible that deficits in cognitive inhibition will emerge in one or both subtypes under these conditions. Conversely, such a study could put to rest the possibility that cognitive inhibition is a core deficit in either ADHD subtype, at least as they are defined in DSM-IV (APA, 2000).

Implications

With each new revision of DSM there has appeared a new definition of ADHD, which may or may not have broken the disorder down into subtypes, including the inattentive subtype. This highlights the importance of determining whether there exists an inattentive subtype of ADHD that can be differentiated from combined type ADHD with respect to cognitive processes. Differentiating subtypes could provide validity to the current taxonomy. Conversely, such findings might provide evidence that the inattentive subtype of ADHD is actually a distinct disorder. Milich et al. (2001) recently addressed this issue. There are several different types of attention, and therefore more than one childhood disorder of attention is likely. Milich et al. argued that children with the inattentive subtype generally have attention deficits that are qualitatively different from children with the combined subtype of ADHD. ADHD-PI children are seen to have a "sluggish cognitive tempo" (e.g. sluggishness, drowsiness, daydreaming) rather than the deficits in distractibility more commonly seen in children with ADHD-C. Their argument that the inattentive subtype is really a distinct and unrelated disorder is an interesting theory requiring further investigation.

The current study evaluated ADHD subtypes with respect to cognitive inhibitory abilities. If cognitive inhibition differentiated the combined and inattentive subtypes, this would have supported the position of Milich et al. (2001). However, the subtypes did not differ in this ability, suggesting that if the combined and inattentive subtypes differ it is not with regard to cognitive inhibition. Although there were limitations to the study, results are consistent with prior research (Gaultney et al., 1999). Nevertheless, more research is needed to rule out cognitive inhibition as a way to differentiate subtypes, particularly in more cognitively developed children and adults. These results should also direct researchers to investigate other abilities that might differentiate subtypes

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Appendix 1

Conditions In Directed Forgetting Procedure

Condition	Presentation	
	Set A	Set B
No Suppression **Recall All**	10 TBR	10 TBR
Suppression **Recall TBR**	10 TBF	10 TBR
Comparison **Recall All**		10 Items
Suppression- RA **Recall All**	10 TBF	10 TBR
Recognition	25 "Old" items 25 Distracters	

Appendix 2

Directions for Directed Forgetting – Adult -- Preliminary Study 1

I am going to show you some pictures and I want you to name them out loud and try to remember those names because I will ask you about some of them later.

No Suppression
After presentation of the first half of the set:

"That was the first half of the set of pictures. I want you to remember those names and the names of the pictures I am about to show you."
After presentation of the second half of the set:

"Okay, tell me the names of all of the pictures that you can."

Suppression
After presentation of the first half of the set:
"Oops, that was the wrong set of pictures. You don't need to remember those. Instead, remember these pictures that I am about to show you."
After presentation of the second half of the set:

"Okay, tell me the names of all the pictures I asked you to remember – those I just showed you. You can say them in any order."

Comparison
"This time I just want you to tell me the names of the pictures you just saw in any order."

Recognition
"I am going to show you some more pictures. Some of them will be the same as some of the pictures you saw earlier and some of them will be different. I want you to say 'yes' to each picture that you saw earlier, and 'no' to each new picture, to the pictures I didn't show you. I know I showed you the wrong list before, so since you saw those pictures you should say 'yes' to those too."

Appendix 3

Directions for Directed Forgetting -- Children

We are going to play a special kind of memory game. I am going to show you some drawings and I want you to name them out loud and try to remember those names, because I am going to ask you about some of them later. I will show you a few sets of drawings. To make it easier, halfway through some of the sets, I will tell whether you should forget the first half of the set, or whether you need to remember both halves. The thing is, you have to try to remember each picture name until this happens because you won't know which names I will ask you about.

No Suppression
After presentation of the first half of the set:

"That was the first half of the set of pictures. I want you to remember those names and the names of the pictures I am about to show you."
After presentation of the second half of the set:

"Okay, tell me the names of all of the pictures you can remember in any order."

Suppression
After presentation of the first half of the set:
"You can forget the names of the pictures I just showed you. Instead remember the names of these pictures."
After presentation of the second half of the set:

"Okay, tell me the names of all the pictures I asked you to remember – those I just showed you. You can say them in any order."

Comparison
"This time I just want you to tell me the names of the pictures you just saw in any order."

Suppression-Recall All
After presentation of the first half of the set:
"You can forget the names of the pictures I just showed you. Instead remember the names of these pictures."
After presentation of the second half of the set:

"I know I told you than you could forget the first few pictures I just showed you, but I want to see if you remember any of them. This time, tell me the names of all of the pictures I just showed you. You can say the words in any order."

Recognition
"I am going to show you some more pictures. Some of them will be the same as some of the pictures you saw earlier and some of them will be different. I want you to say 'yes' to

each picture that you saw earlier, even if you didn't have to remember the picture name. Say 'no' to each new picture, to the pictures I didn't show you."