Journal of Attention Disorders
Volume 8 Number 3
February 2005 96-108

10.1177/1087054705277265
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Self-Regulation and Inhibition in Comorbid ADHD Children: An Evaluation of Executive Functions

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The relationship between executive function and comorbid diagnoses in ADHD children is examined. One hundred six children between 7 and 15 years of age are assessed using the Tower of London (TOL), a test of executive function, and the Kiddie Schedule of Affective Disorders and Schizophrenia, Present and Lifetime Version, a diagnostic interview. All children met the diagnostic criteria for ADHD. A majority of the children had comorbid anxiety disorders, mood disorders, or oppositional defiant disorder. Measures on the TOL are total move score, total initiation time, and total rule violations. Age is predictive in all three measures of executive function as assessed by the TOL. Gender is predictive of total initiation time and total rule violations. Comorbid disorders are found to not have significance on executive function as measured by the TOL. This study concludes that comorbid disorders may not affect executive function. *(J. of Att. Dis. 2005;8(3), 96-108)*

Keywords: *ADHD; ADD; hyperactivity; executive function; oppositional defiant disorder; mood disorder; anxiety disorder; comorbid disorder; self-regulation; inhibition; working memory; frontal lobes; brain function*

Considering the fact that ADHD costs millions a year in treatment and has lasting effects into adulthood, it is imperative that it should be studied more thoroughly. This will result not only in discovering a more theoretically based etiology of ADHD and comorbid disorders but also in finding a more efficient and cost-effective method for diagnosing and treating children and adults with ADHD and comorbid disorders (Leibson, Katusic, Barbaresi, Ransom, & O'Brien, 2001). Pineda, Ardila, and Rosselli (1999) wrote that ADHD is a "public health pediatric disorder that needs special attention to prevention and treatment" (p. 159). Although ADHD is one of the most commonly diagnosed mental disorders (Conners & Jett, 1999), the proportion of research conducted, especially regarding comorbidity and dysfunctions of the brain, is very small (Barkley, 1998).

If a relationship can be determined between ADHD, comorbid disorders, and the executive functions, new interventions may be developed, and more effective medication for comorbid disorders can be prescribed (Seidman et al., 1995). It is important to study all hypotheses of comorbidity to determine what causes this disorder and to explore whether it can be treated more effectively or even prevented. Most hypotheses of ADHD and comorbidity have little empirical evidence to support their proposed ideas of etiology or treatment. Relatively little research is available regarding the medical aspects of ADHD and comorbidities, especially regarding the executive functions of the brain. Instruments that measure executive function have been used only minimally in ADHD and comorbidity research (Culbertson & Zillmer, 1999). They have been used to determine executive functions in impairments such as brain injury or Parkinson's disease but not in ADHD and comorbid disorders.

Little research has been conducted to determine any possible correlation between comorbid disorders and ADHD. It is not known how much comorbid disorders affect the level of functioning in ADHD children. There is

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also little research determining the effect of ADHD and comorbidity on the executive function system. It is not known whether ADHD and comorbid disorders are entirely exclusive of each other, with only ADHD affecting the executive functions, or if both ADHD and comorbid disorders affect executive functions (Biederman, Faraone, Keenan, Steingard, & Tsuang, 1991; Schachar & Tannock, 1995).

Studies examining the correlation between age and executive functions in ADHD children are insufficient. It is not known how much age influences the executive functions in the brain, particularly in children with ADHD. It is unclear whether the executive functions of the brain improve along with development. By examining the medical aspects of ADHD, it may be possible to eventually have unified diagnostic criteria for ADHD (Barkley, 1998). By examining the relationship between ADHD, comorbidity, executive functions, and age, this study adds to the relatively new research regarding the role of brain function in the diagnosis and treatment of this disorder. It may also create more appropriate assessments and treatment of ADHD (Jensen et al., 1999).

The purpose of this study is to examine the relationships between executive functions, comorbid diagnoses of ADHD, age, and gender. By examining these relationships, this study adds to the accruing research regarding the role of the brain and its functions in relation to ADHD and its comorbid disorders. It also adds to the research regarding the developmental progression of ADHD and comorbidity and differences in ADHD and comorbidity between the genders.

Many hypotheses of ADHD exist, but few incorporate the concepts of disinhibition, comorbid disorders, neurological functions, and developmental progression of the disorder into one framework. ADHD is viewed not as a problem with inattention but as a problem with disinhibition and self-regulation of behaviors (Barkley, 1991). Disinhibition occurs when the impulses and urges to act cannot be controlled. Self-regulation happens when we actively choose to control behaviors (Barkley, 1997). This hypothesis contends that disinhibition and problems with self-regulation lead to a dysfunction of the executive system in the brain, which regulates and organizes behavior. ADHD is believed to be a problem with the performance of the executive system and not a disorder of intelligence or knowledge. This means that people with ADHD know what behaviors they need to display but are unable to do so because of the dysfunction of the executive system (R. A. Barkley, personal communication, March 31, 2000).

Comorbidity is very common in people with ADHD. As many as 93% of ADHD children and adolescents may have comorbid disorders (Bird, Gould, & Staghezza, 1993). In a study by The Multimodal Treatment Study of Children With ADHD (MTA) Cooperative Group (1999), 579 ADHD children were studied. Of those children, 40% had comorbid oppositional defiant disorder (ODD), and 34% had comorbid anxiety disorders. Each comorbid disorder increases the impairment of the ADHD child (Gorman, 2001). Rates of comorbid disorders can differ according to the subtype of ADHD. Children with the combined or inattentive subtypes of ADHD have been found to have a higher rate of depression than the hyperactive-impulsive subtype (Faraone, Biederman, Weber, & Russell, 1998; Willcutt, Pennington, Chhabildas, Friedman, & Alexander, 1999). In a study by Faraone et al. (1998), the combined subtype of ADHD had a higher rate of conduct disorder (CD), ODD, and bipolar disorder than the inattentive or combined subtypes.

Children with ADHD may display more difficulties with executive functions if they have comorbid disorders, such as generalized anxiety disorder, CD, and ODD, or a reading disorder (Willcutt, Pennington, Boada, et al., 1999). It is not known whether problems with executive functions are solely a characteristic of ADHD or if other disorders also demonstrate difficulties with executive functions. This is important to know when determining if certain comorbid disorders can actually compound the impairment of the ADHD child by increasing executive dysfunction (Barkley, 1998).

It is unknown what role comorbid disorders of ADHD have regarding executive function. In a study by Tannock, Ickowicz, and Schachar (1995), ADHD children with comorbid anxiety did not have improved working memory, an executive function, after treatment with methylphenidate. However, ADHD children without comorbid anxiety did have improved working memory after treatment. The methylphenidate reduced the activity levels in both groups (Tannock et al., 1995). In a study by Pliszka (1989), ADHD children with comorbid anxiety were less impulsive and had a weaker response to methylphenidate than the noncomorbid group. It is the purpose of this study to examine what impact, if any, comorbidity has on executive function.

Because this hypothesis contends that executive functions improve as children get older, this study also examines the impact of age on executive function performance. In a study by Krikorian, Bartok, and Gay (1994), a test of executive function was administered to 205 elementary school students and 74 young adults. In studies by

Krikorian et al. (1994) and Levin et al. (1991), as participants got older, performance on executive function measurements improved.

Gender and executive function performance are also examined because of the occurrence of more boys than girls being diagnosed with ADHD. This study used the Kiddie Schedule of Affective Disorders and Schizophrenia, Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997) and the Tower of London (TOL; Culbertson & Zillmer, 1998b) to examine these variables.

The following were the independent variables of this study: age, gender, and the common comorbid disorders of ADHD (ODD, anxiety disorders, and mood disorders). Age was examined because of the premise that executive functions of children improve throughout time (Barkley, 1997; Gnys & Willis, 1991; Levin et al., 1996; Pennington, Bennetoo, McAleer, Roberts, & Krasnegor, 1996). In a study by Levin et al. (1991), non-ADHD children had increased development of their executive function skills around the ages of 7 and 8 and then from 9 to 12. At this time, executive functions move from externalization to internalization. Externalization means that children's behaviors are regulated by external reinforcers, such as punishments and rewards (Barkley, 1997, 1998; R. A. Barkley, personal communication, March 31, 2000). Executive functions become more internalized with age, meaning the child can now inhibit and self-regulate his or her own behaviors.

Method

Participants

One hundred three children 7 to 15 years old were recruited for this study. The age group of 7 to 15 was selected because children 7 to 15 years of age have an increased development over other age groups in the executive functions of the brain (Levin et al., 1991). Children were recruited through advertisement and referrals in the north central Florida region. Twelve counties were represented in the sample.

To qualify for the study, children must have met the K-SADS-PL diagnostic criteria for ADHD, as administered by the principal investigator, and either anxiety disorders, ODD, or mood disorders, as assessed by an independent rater. Children who met the diagnostic criteria for only ADHD were also included in the sample. Of the children recruited, a total of 100 children met screening criteria and were included in the sample. Four children refused to complete the TOL test. One child was eliminated because of difficulty manipulating the computer mouse. Children were not taking any stimulant medication at the time of the assessment.

Procedures

The study sampled children with a previous clinical diagnosis or symptoms of ADHD and either anxiety disorders, ODD, or mood disorders. There were two phases in data collection. First, the principal investigator observed the child and asked him or her and the primary caregiver about the child's symptoms of ADHD. The ADHD subsection of the K-SADS-PL was used to determine an ADHD diagnosis. If the child met the criteria for ADHD, an independent rater administered the K-SADS-PL to determine the presence of anxiety disorders, ODD, and mood disorders. After completion of the interview, the TOL was administered to the child by another independent rater. The raters were only cognizant of the results of their particular instrument. To ensure rater accuracy, the primary investigator performed random checks by observing K-SADS-PL interviews and TOL administration.

Measures

TOL. The TOL is a standardized test of executive function in children and was originally developed by Shallice (1982). It was then revised and standardized by Culbertson and Zillmer (1999). Keith Berg (personal communication, August 31, 2001; December 12, 2001; January 15, 2002) created a computerized version of this test in 2000. Berg's TOL uses the same problem sets as Culbertson and Zillmer's 1999 version. The TOL measures the executive functions of planning, working memory, and forethought (Welsh & Pennington, 1988).

The original TOL is an instrument that comprises a wooden board with three pegs of increasing heights. There are also three colored wooden balls, one each colored green, red, and blue. The rater demonstrates 10 different patterns of balls. The child then attempts to recreate the different patterns starting with a set start pattern on each problem. The computerized version of the TOL consists of a screen with two game boards. The top of the screen displays the computer's game board with the goal pattern of balls. On the bottom of the screen is the child's game board. Each problem starts with the child's board displaying the start pattern. The child clicks on the balls to move them to different pegs and, after completion, clicks on a prompt to continue to the next problem. The program records the child's total move score, initiation time, and total rule violations on a spreadsheet, which was printed out at the end of testing (Keith Berg, personal communication, August 31, 2001, December 12, 2001, January 15, 2002; Culbertson & Zillmer, 1999).

Children were evaluated on three dependent variable scores of executive function assessed by the TOL Deluxe: (a) total move score, (b) total initiation time, and (c) total number of rule violations. The total move score is the sum of the moves for all 10 TOL problems. A move is recorded when a child completely takes a ball off a peg and then either places it on another peg or replaces it onto the same peg (Culbertson & Zillmer, 1999). Total move score is calculated by subtracting the TOL's recommended number of moves from the number of moves it takes the child to solve the problem. This equation is done to "allow for representation and differentiation of a wide range of individual differences in executive function" (Culbertson & Zillmer, 1998b, p. 290). The total number of moves from all the test problems is then added, resulting in the total move score. The function of moving the balls employs the executive functions of working memory, forethought, and planning, whereas the total move score of the TOL measures the executive functions of inhibition, planning, and problem solving (Barkley, 1998; Culbertson & Zillmer, 1998a, 1998b, 1999; Gnys & Willis, 1991; Murji & DeLuca, 1998; Pennington et al., 1996; Schnirman, Welsh, & Retzlaff, 1998). The higher a child's total move score, the poorer his or her executive function planning ability (Culbertson & Zillmer, 1999). Children with ADHD consistently take significantly more total moves on the TOL than non-ADHD children (Culbertson & Zillmer, 1998a, 1999).

Total initiation time is the amount of planning time between when the child is told by the examiner to begin the pattern and when they actually remove the first ball from the peg (Culbertson & Zillmer, 1999). Initiation time is when children usually look forward in time and visually imagine the sequence of which to place the balls (Baker et al., 1996). In a study by Levin et al. (1996), total initiation time on the TOL was found to load on a factor of inhibition. Thus, the total initiation time score is a valid measurement of a child's executive function impulsivity, a hallmark feature of ADHD (Murji & DeLuca, 1998).

Total rule violations consist of the sum for each subject of any violations of Rule Type I and Rule Type II and the number of problems unsolved after 1 min. A Rule Type I violation is committed when a child places more balls on a peg than it can hold. A Rule II violation is committed when a child removes two or more balls from a peg at the same time or places a ball on the table rather than on a peg (Levin et al., 1994). This rule, however, could not be incorporated into the computerized TOL. Therefore, a Rule II violation was then defined as a child attempting to move a ball that was underneath another on the peg. A rule violation is also committed if a child cannot complete a problem within 1 min. The number of Rule I violations and Rule II violations and the number of problems unsolved after 1 min were summed for a total rule violations score. When a Rule I violation was committed, the TOL program automatically placed the ball at its previous peg. If a child has a poor total move score and a high number of rule violations, his or her executive function difficulties are related to problems with self-regulation of behavior and working memory (Culbertson & Zillmer, 1999). Number of rules broken also relates to the executive function of executive planning, inhibition, and use of internal speech to guide behavior (Culbertson & Zillmer, 1998a, 1998b, 1999). It also shows difficulty with working memory because of the inability of the brain to retain knowledge of rules and apply those rules (Culbertson & Zillmer, 1999; Roberts & Pennington, 1996). In a study by Levin et al. (1996), the number of broken rules was found to load on a factor of planning.

K-SADS-PL. The K-SADS-PL is a semistructured diagnostic interview based on *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV;* American Psychiatric Association, 1994) diagnostic criteria. A trained clinician can interview the child and the parent either together or separately. The entire interview can diagnose up to 32 Axis I child psychiatric disorders. The K-SADS-PL provides both current and lifetime diagnostic ratings (Kaufman et al., 1997). The affective disorder, anxiety disorder, and behavioral disorder subsections of the K-SADS-PL were used in this study. The affective disorders screened in the K-SADS-PL were major depressive disorder (MDD) and mania. The anxiety disorders examined were panic disorder, separation anxiety disorder, agoraphobia, generalized anxiety disorder, and obsessive-compulsive disorder. The behavioral disorders examined were ADHD and ODD.

Results

Sample Characteristics

Ninety-five 7- to 15-year-old children (69 males and 26 females, mean age = 11 years and 6 months) were included in the sample. The sample was predominantly Caucasian (see Table 1). The average age of the sample was 11 years and 6 months. Males on average were older than females (see Table 2). The range of age was from 7 years and 6 months to 15 years and 11.5 months.

Table 1
Demographics of Sample (N = 96)

Variable	n	%
Gender		
Male	69	72.6
Female	26	27.4
Ethnicity		
Caucasian	86	90.5
African American	6	6.3
Hispanic	3	3.2

Table 2
Age Demographics of Sample (N = 96)

Variable	Mean Age (Months)	Mean Age (Years, Months)
Total sample	138.42	11, 6
Gender		
Male	132	11, 11
Female	124	10, 4

Out of the sample, 20 children (21%) had only ADHD. This group comprised 21.7% of the boys and 15.38% of the girls from the total sample. Out of the total sample, 50 children (52.6%) had comorbid ODD. Out of these 50 children, 26 (52%) had other comorbid diagnoses. Forty-two children (44.2%) had an anxiety disorder. Out of these 42 children, 30 (71.4%) had other comorbid diagnoses. Twenty-nine children (30.5%) had a mood disorder. Out of these 29 children, 26 (89.7%) had other comorbid diagnoses. Thirty-nine children (41%) had only one comorbid disorder. The total number of children with two comorbid disorders was 26 (27.4%). Ten children (10.5%) had all three disorders. Prevalence of comorbid disorders by gender is provided in Table 3.

In regard to the total rule violations score, there were a total of 116 problems that were unsolved after 1 min. The male participants had 77 problems unsolved after 1 min, an average of 1.1159 per male participant. The female participants had 39 problems unsolved after 1 min, an average of 1.5 per female participant. Out of the sample, the total number of Type I rule violations was 165, and the total number of Type II rule violations was 266. The males had a total of 114 Type I rule violations, an average of 1.6522 Type I rule violations per male participant. The females had a total of 51 Type I rule violations, an average of 1.9615 Type I rule violations per female participant. The males had a total of 184 Type II rule violations, an average of 2.6667 per male participant. The females had a total of 82 Type II rule violations, an average of 3.1538 per female participant.

Table 3
Comorbid Disorders by Gender

Variable	n	%
Male		
Total	69	72.6
No comorbid disorders	15	21.7
Oppositional defiant disorder	37	53.9
Anxiety disorder	36	52.2
Mood disorder	23	33
Female		
Total	26	27.4
No comorbid disorders	4	15.38
Oppositional defiant disorder	14	53.85
Anxiety disorder	13	50
Mood disorder	6	23

Data Analytic Procedures

Standard multiple regression procedures were used to assess the relationship of age, gender, and comorbid diagnoses of anxiety disorders, ODD, and mood disorders with three variables of executive function measured by the TOL: (a) total move score, (b) total initiation time, and (c) total rule violations. Interrater reliability was determined by using a contingency coefficient. The raters agreed on diagnoses for 25 out of 30 participants, or .86. For the 5 remaining participants, both raters had matched all diagnoses, but one of the raters had written down additional diagnoses. From the 30 participants, there were a total of 74 diagnoses. The raters matched on 59 of these diagnoses, or .79.

Total Move Score

The multiple regression analysis performed on the total move score demonstrated that the full model was significant (p = .0001). Examination of the individual predictors found that age was the only significant predictor of the set of independent variables (p = .0000). Interpreting the model, as age increases, the number of expected total moves decreases by .3669 s per month of age. The full model is provided in Table 4.

Total Initiation Time

The multiple regression analysis performed on the initiation time demonstrated that the full model was significant (p = .0020). Examination of the individual predictors found that age was significant (p = .0051) and gender was significant (p = .0140). Interpreting the model, as age increases, the expected initiation time decreases by .1309 s per month of age. Additionally, males take an average of

Table 4
Total Move Score: Full Model

Independent Variable	*B*	t(89)	*p*
Intercept	89.2630	8.2196	< .0001
Gender	–3.6207	–0.8168	.4162
Age	–0.3669	–5.2209	< .0001
Oppositional defiant disorder	0.7934	0.2051	.8380
Anxiety	–3.8681	–0.9403	.3496
Mood	6.6795	1.4839	.1414

Table 5
Total Initiation Time: Full Model

Independent Variable	*B*	t(89)	*p*
Intercept	69.9538	9.9270	< .0001
Gender	–7.2110	–2.5068	.0140
Age	–0.1309	–2.8695	.0051
Oppositional defiant disorder	2.9062	1.1576	.2501
Anxiety	2.2430	0.8402	.4030
Mood	–0.8316	–0.2847	.7765

7.211 s less to initiate moves than females. The full model is provided in Table 5.

Total Rule Violations

The multiple regression analysis performed on total rule violations demonstrated that the full model was significant ($p = .0001$). Examination of the individual predictors found that age was significant ($p = .0000$) and gender approached significance ($p = .0529$). Interpreting the model, as age increases, the expected number of total rule violations decreases by .1812 violations per month of age. Additionally, males perform an average of 4.8338 fewer rule violations than females. The full model is provided in Table 6.

Discussion

Age Effects

In this study, initiation time decreased as children got older. As age increased, children used less time to plan their strategies before making their first move. It is possible that as ADHD children get older, they need less time to acquire a plan before beginning a TOL task and that they become more aware of time limitations (Barkley, 1997).

Table 6
Total Rule Violations: Full Model

Independent Variable	*B*	t(89)	*p*
Intercept	34.5105	5.7168	< .0001
Gender	–4.8338	–1.9162	.5294
Age	–0.1812	–4.6387	< .0001
Oppositional defiant disorder	2.1025	0.9776	.3309
Anxiety	–1.4689	–0.6423	.5223
Mood	0.9476	0.3787	.7058

For every month of age, the number of total rule violations decreased by .18. This may occur because of the continuing development of the executive functions of impulse control and reconstitution. Reconstitution is the ability to take rules given to the brain and apply these rules to a particular situation, in this case the TOL (Barkley, 1998). According to Welsh, Pennington, and Grossier (1991), impulsivity does not reach the developmental level of an adult until the age of 10, and reconstitution is not fully formed until adolescence. Therefore, an improvement in complying with rules with an increase in age would support a developmental view of the nature of executive functions.

Gender Effects

In this study, gender was predictive of initiation time. Boys were found to have a shorter total initiation time than girls by 7.21 s. According to Culbertson and Zillmer (1998a), a quicker initiation time denotes difficulties with impulsivity, inhibition, disorganization, and planning. Also, boys' executive functions may mature at a slower rate than girls. Boys may also need less time to plan their moves. This could mean that boys were more impulsive when beginning a TOL problem or that they knew how to solve the problem faster, on average, than girls.

This study also found that males on average had fewer rule violations than females. In a study by Culbertson and Zillmer (1998a), older female children had more rule violations than males, showing an increase in executive function impairment. However, other studies show that males have more executive function impairment than females. Although males have more overall difficulty with executive function, they may be better at the executive function tasks measured by the rule violation score. Although gender predicted initiation time and rule violations, it did not predict total move score. Other studies have found that there is no difference in TOL initiation time, total moves, or rule violations in male and female ADHD children (Culbertson & Zillmer, 1998a).

Comorbid Disorder Effects

This study found that ODD and anxiety disorders did not predict the total move score. Also, the presence of ODD, anxiety disorders, and mood disorders were not predictive of rule violations or initiation time. The presence of mood disorders did not predict total move score, although children with mood disorders took more moves to solve a TOL problem than other children did. This may be caused by depression symptoms of psychomotor retardation, fatigue, or reduced ability to concentrate (American Psychiatric Association, 1994). However, more research would need to be conducted to differentiate concentration difficulties as either being from ADHD or MDD.

In this study, there was no relationship between comorbid diagnoses and executive function as assessed by the TOL. In other studies, comorbidity was also not found to add additional impairment to the executive functions of ADHD children (R. A. Barkley, personal communication, January 2, 2001). It may be that comorbid disorders do not influence the executive functions of ADHD children or that the TOL is not capable of detecting the influence of comorbid disorders on executive function. In a study by Pillow, Pelham, Hoza, Molina, and Stultz (1998), the authors felt that although disinhibition was a common factor in both ODD and ADHD, a limitation in the instruments may mistake the disinhibition as the same for both disorders. The authors contend that the disinhibition in ADHD is nonvolitional, whereas the disinhibition in ODD is by choice. They state that instruments may show a correlation between disinhibition, ADHD, and ODD when in fact they are separate disorders (Pillow et al., 1998). In this study, however, the TOL was not capable of detecting the influence of comorbid disorders on executive function, including disinhibition.

Limitations

Primary caregivers reported on the child's behaviors for the K-SADS-PL. There was a possibility that the information given about the child was not accurate. Caregivers may overlook children's symptoms of anxiety and depression. This is caused by the internalizing nature of these disorders (Pliszka, Carlson, & Swanson, 1999). Also, even though such diagnostic measures as the K-SADS-PL have been evaluated numerous times, a child may be given a diagnosis when one is not warranted. Other disorders that the child may actually have may be overlooked (Gall, Borg, & Gall, 1996).

Although children were asked to discontinue their stimulant medication before the test, some children were taking other psychotropic medications for anxiety and depression. Because of the chemical nature of these medications, it was unsafe to have children discontinue them just for this study. These antidepressants may have reduced ADHD behavior and artificially improved the child's performance on the TOL because of improvement of the executive function system (Popper, 2000).

Some of the children with ODD may have willfully disregarded the rules of the TOL, resulting in an inaccurate portrayal of their abilities (Gresham, 2000). Children with dyslexia had difficulty with one TOL problem that appeared to be identical to the start pattern, except for transposed colors on one peg. Children with dyslexia would comment that the problem was already solved. Because the children took longer to recognize the transposed colors, there may have been inaccurate measurements of the children's abilities.

Summary

In this study, initiation time decreased as children got older. As age increased, children used less time to plan their strategies before making their first move. It is possible that as ADHD children get older, they need less time to acquire a plan before beginning a TOL task, and they become more aware of time limitations (Barkley, 1997). Increased awareness of time limitations may be a result of executive function development in the area of working memory (Barkley, 1998). Children with ADHD may also have an increase in motivation as they get older. The ability to direct one's behavior toward a goal, also referred to as drive or motivation, is one of the executive functions in the brain (Barkley, 1998).

For every month of age, the number of total rule violations decreased by .18. This may occur because of the continuing development of the executive functions of impulse control and reconstitution. Reconstitution is the ability to take rules given to the brain and apply these rules to a particular situation, in this case the TOL (Barkley, 1998). According to Welsh et al. (1991), impulsivity does not reach the developmental level of an adult until the age of 10, and reconstitution is not fully formed until adolescence. Therefore, an improvement in complying with rules with an increase in age would support a developmental view of the nature of executive functions.

Similar to this study, other research has shown that as children get older, performance on executive function measurements, such as the Wisconsin Card Sorting Test and the Stroop Color Word Test, improves (Anderson, Anderson, & Lajoie, 1996; Culbertson & Zillmer, 1998b;

Levin et al., 1991; Siegel & Ryan, 1989). In a study by Mezzacappa, Kindlon, and Earls (1999), children between 6 and 16 years of age with externalizing behavior disorders, including ADHD, had an improvement throughout time on scales of executive function. In a study by Culbertson and Zillmer (1998b), TOL total move scores and number of rule violations of ADHD children decreased with age. Studies of previous versions of the TOL also found age-related improvement of the total move score (Culbertson & Zillmer, 1998a). Studies have also found that as children got older, initiation time on the TOL decreases.

Changes in executive functions throughout time may be related to developmental changes in the brain (Barkley, 1998; Denckla, 1996). Welsh et al. (1991) found that children reached the executive function abilities of an adult at different ages. Planning and organization were at an adult level by 6 years of age. Impulse control was achieved by age 10, and complex planning, sequencing, and reconstitution was at an adult level in adolescence (Welsh et al., 1991). Although children with ADHD do not reach the same level as non-ADHD children in executive function, they do have an age-correlated improvement, as seen in children without ADHD (Barkley, 1998).

In this study, gender was predictive of initiation time. Boys were found to have a shorter total initiation time than girls by 7.21 s. According to Culbertson and Zillmer (1998a), a quicker initiation time denotes difficulties with impulsivity, inhibition, disorganization, and difficulty with planning. Also, boys' executive functions may mature at a slower rate than girls' executive functions. Boys may also need less time to plan their moves. This could mean that boys were more impulsive when beginning a TOL problem or that they knew how to solve the problem faster, on average, than girls.

This study also found that males on average had fewer rule violations than females. In a study by Culbertson and Zillmer (1998a), older female children had more rule violations than males, showing an increase in executive function impairment. However, other studies show that males have more executive function impairment than females. Although males have more overall difficulty with executive function, they may be better at the executive function tasks measured by the rule violation score. Although gender predicted initiation time and rule violations, it did not predict total move score. Other studies have found that there is no difference in TOL initiation time, total moves, or rule violations in male and female ADHD children (Culbertson & Zillmer, 1998a).

Unfortunately, most ADHD research samples have been primarily male (Gershon, 2002; Seidman et al., 1997). This may be caused by the 3:1 ratio of males to females diagnosed with ADHD or the fact that males exhibit the more disruptive behaviors of ADHD, as seen in the hyperactive and impulsive subtypes, whereas females exhibit the quieter aspects of the inattentive subtype. Because of this more frequent disruptive behavior, more males than females are referred for ADHD treatment (Barkley, 1997; Quinn & Nadeau, 2000). Even when studies on executive function did include females, the sample was very small (Seidman et al., 1997). In a review of executive function studies, 8 of 13 studies included ADHD girls in the sample. Out of these studies, the mean sample size was 28 boys and only 7 girls per study (Corkum & Siegel, 1993).

In research studies, girls were found to have fewer problems with inhibition than boys were. In a study of 498 ADHD children, girls were found to be less impulsive than boys on a test of executive function (MTA Cooperative Group, 1999). In a study by Gershon (2002), ADHD females were rated by parents and teachers as less hyperactive and inattentive than ADHD males. Girls were found to have less of an executive function deficit than boys in a study by Biederman et al. (1999). The authors state that girls "may have a less complicated neuropsychological course" of ADHD than boys (Biederman et al., 1999, p. 8). In a study by Seidman et al. (1997), girls with ADHD had less impairment on tests of executive function than did ADHD boys. The authors concluded that "girls with ADHD may be less vulnerable to executive function deficits than boys" (Seidman et al., 1997, p. 366).

This study found that ODD and anxiety disorders did not predict total move score. Also, the presence of ODD, anxiety disorders, and mood disorders were not predictive of rule violations or initiation time. In a case study by Culbertson and Zillmer (1999), an 11-year-old boy who was diagnosed with ADHD and ODD was assessed using the TOL. Although the boy's total move score fell in the average range for an ADHD child, his number of total rule violations was in the first percentile when compared to children with only ADHD. The relationship between ADHD, comorbid disorders, and executive function is still ambiguous. There is little research regarding this relationship (Gershon, 2002). It is unclear whether comorbid disorders affect the executive function system or if comorbid disorders are completely separate from ADHD and therefore do not affect executive function (Biederman, Newcorn, & Sprich, 1991; Schachar & Tannock, 1995).

The presence of mood disorders did not predict total move score; although, children with mood disorders took more moves to solve a TOL problem as compared to other children. This may be caused by depression symptoms of psychomotor retardation, fatigue, or reduced ability to concentrate (American Psychiatric Association, 1994). However, more research would need to be conducted to differentiate concentration difficulties as either being from ADHD or MDD.

In this study, there was no relationship between comorbid diagnoses and executive function as assessed by the TOL. In other studies, comorbidity was also not found to add additional impairment to the executive functions of ADHD children (R. A. Barkley, personal communication, January 2, 2001). It may be that comorbid disorders do not influence the executive functions of ADHD children or that the TOL is not capable of detecting the influence of comorbid disorders on executive function. In a study by Pillow et al. (1998), the authors felt that although disinhibition was a common factor in both ODD and ADHD, a limitation in the instruments may mistake the disinhibition as the same for both disorders. The authors contend that the disinhibition in ADHD is nonvolitional, whereas the disinhibition in ODD is by choice. They state that instruments may show a correlation between disinhibition, ADHD, and ODD when in fact they are separate disorders (Pillow et al., 1998). In this study, however, the TOL was not capable of detecting the influence of comorbid disorders on executive function, including disinhibition.

The relationship between ADHD, comorbid disorders, and executive function is important because of the large number of children who are in this category. If more is known about this relationship, treatments such as psychotherapy and medication can be tailored to the child's specific issues rather than using a general approach that does not differentiate between the presence and absence of a comorbid condition. Knowing more about the relationship between the disorders may also allow for the formation of early interventions for children (Biederman, Newcorn, et al., 1991).

Results of other research studies are varied. Some show a definite correlation between executive function and comorbid disorders and ADHD, whereas others show no correlation or even an improvement of executive function when a comorbid disorder is present (Schachar & Tannock, 1995). A study by Mezzacappa et al. (1999) found that on measures of executive function, children with externalizing behavior disorders, such as ADHD and ODD, scored significantly worse than controls, but performance on these scales improved with age. Children with externalizing behavioral disorders had executive functions that matured at the same rate as the control group but never reached the same level as the control group. In a study by Gershon (2002), ADHD females were also found to have less externalizing symptoms, such as in ODD. They were also found to have more internalizing symptoms, as in depression and anxiety, than ADHD males.

In a study by Schachar and Tannock (1995), executive function difficulties in ADHD children were evident regardless of comorbidity. The authors conclude that executive function difficulties may only occur in ADHD and not in comorbid disorders.

In studies by Schachar, Tannock, and Logan (1993) and Schachar and Tannock (1995), children with comorbid ADHD and CD actually showed fewer difficulties with inhibitory control and executive function than children with ADHD only.

A study by Schachar, Mota, Logan, Tannock, and Klim (2000) found that children with ADHD scored worse on a test of executive function compared to controls, children with CD, and children with ADHD and CD. The authors concluded that CD may not be a variant of ADHD but rather an entirely separate disorder (Schachar et al., 2000). In a similar study by Oosterlaan, Logan, and Sergeant (1998), children with ADHD only and children with ADHD and CD were compared on a test of executive function. The authors found that children with ADHD and CD had the same level of executive dysfunction as children with ADHD alone.

Implications of Findings

General Implications for Hypotheses

There are three main hypotheses regarding the origin, etiology, and relationship of ADHD and comorbid disorders. In the first hypothesis, ADHD and comorbid disorders are seen as separate disorders, completely independent of each other in terms of origin, course, treatment, and symptomatology. In another, ADHD and comorbid disorders have different courses of development but have similar risk factors. In the third, it is believed that although a child may have symptoms of a comorbid disorder, it is only the child's ADHD that is imitating these symptoms. Therefore, the child may not actually have that comorbid disorder (Schachar & Tannock, 1995). In this study, the comorbid disorders, ODD, anxiety disorders, and mood disorders did not predict executive function performance. This finding supports the hypothesis that ADHD may be a separate disorder with its own unique impact on the executive functions of the brain.

The finding that age was predictive of total move score, initiation time, and rule violations supports the hypothesis that executive functions develop and improve throughout time (Barkley, 1996, 1997, 1998). The prefrontal region of the brain, which houses executive functions, has a great maturation in function between 5 and 12 years of age (Barkley, 1997; Levin et al., 1994; Welsh & Pennington, 1988). The finding that ADHD is a developmental disorder may help change the ADHD age of onset criteria of in the *DSM-IV* (American Psychiatric Association, 1994; Brown, 2000). If executive functions develop at different rates, children may not show difficulties with these functions until later in life when executive function demands increase (Brown, 2000). Therefore, the age of onset in diagnostic criteria (American Psychiatric Association, 1994) could be broadened or eliminated (Barkley & Biederman, 1997; Brown, 2000).

In this study, gender predicted initiation time. Boys on average had a shorter initiation time than girls. Because a shorter initiation time demonstrates difficulty with impulsivity, inhibition, disorganization, and lack of planning, boys with ADHD may be more impulsive and have fewer planning skills than ADHD girls. In a study by Biederman et al. (1999), girls with ADHD on average scored higher than ADHD boys on the Global Assessment of Functioning Scale. In this study, gender was shown to be predictive of initiation time. Boys on average had a shorter initiation time than girls. A shorter initiation time is more common in ADHD children than in controls (Culbertson & Zillmer, 1998a). Boys with ADHD may be more impulsive and have fewer planning skills than ADHD girls. Therefore, this would appear to support the hypothesis that girls with ADHD appear to have a less severe form than ADHD boys do.

According to a study by Biederman et al. (1999), ADHD boys are more likely than ADHD girls to have comorbid CD, and both genders have an equal amount of comorbid anxiety disorders and mood disorders. Other studies show that ADHD girls are more likely than ADHD boys to have comorbid anxiety disorders and comorbid mood disorders (Biederman et al., 1999; Gaub & Carlson, 1997). In this study, boys with ADHD had on average fewer rule violations than girls. The rule violations score measures the executive functions of inhibition, planning, problem solving, and use of internal speech (Barkley, 1998; Culbertson & Zillmer, 1998a, 1998b, 1999; Gnys & Willis, 1991; Murji & DeLuca, 1998; Pennington et al., 1996; Schnirman et al., 1998). This may mean that because initiation time and rule violations measure different aspects of executive functions, males and females may differ on their competency on individual functions. Therefore, gender may influence which executive functions are superior to others.

General Implications for Research

There are several research directions that could emerge from this study. Some studies have shown that girls with ADHD may present in a different way than ADHD boys (Biederman et al., 1999). However, because there is such limited research in this area, it is difficult to interpret the relationship between ADHD and gender. Because this study demonstrated a predictive relationship between gender and some TOL measures, more research needs to be conducted regarding the influence of gender on ADHD in general and executive functions and comorbid disorders specifically. Most research on ADHD has been conducted with a male sample (Biederman et al., 1999). Research needs to focus on whether one gender is more at risk for developing ADHD and comorbid disorders and which comorbid diagnoses are more prevalent in each gender (Barkley, 1998).

From the results of this study, the TOL does not appear to be influenced by comorbid disorders. When assessing the role of ADHD and comorbid disorders on executive function, other instruments besides the TOL should be used. This may determine if there really is a difference in comorbid disorders and brain functioning and if the TOL is just not designed to assess the impact of these disorders. Assessing ADHD, comorbid disorders, and executive function may yield a dimensional view of ADHD rather than a categorical one. A dimensional view of ADHD is one in which there is a continuum of ADHD disorders, with comorbid disorders and executive functions determining the type of ADHD, rather than in the categorical view, where there is one disorder with two subtypes only (American Psychiatric Association, 1994; Brown, 2000).

General Implications for Practice

A clinician may have a better understanding of the ADHD client when comorbid disorders are examined. Administering the TOL throughout time may help the clinician determine the rate of development of the executive functions in the brain. It may also help explain why ADHD symptoms, such as disinhibition and hyperactivity, appear to improve as children get older. More appropriate assessments and treatment of ADHD may be created by taking into account the influence of age on executive function (Jensen et al., 1999). The TOL may also help clinicians explain how clients may have different presentations of ADHD based on gender. There may be different aspects of executive function at which each gender excels, as evidenced by gender predicting initiation time and rule violations. For example, because boys have more difficulty with disruptive behavior, they may have more difficulty with the executive function of inhibition than girls would.

If it is discovered that ADHD and comorbid disorders truly are completely separate disorders, a clinician may consider one disorder to be the primary disorder and others as secondary disorders, thereby focusing on the symptomatology of the primary disorder first in psychotherapy. From a pharmacological point of view, two medications, one for each disorder, may be warranted. This study and others suggest that ADHD may have a separate foundation and course from other disorders. A medication for ADHD, which targets the frontal lobes of the brain, may not be as effective in other disorders, such as depression (Pliszka, 1989). In counseling practice, a treatment plan and goals could focus on two disorders as separate entities, with separate objectives and treatment goals for each.

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