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Differential Performance of Post-traumatic stress disorder (PTSD), Attention deficit hyperactivity disorder (ADHD), and a Non-Clinical Control Group on Tests of Attention and Inhibition

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Abstract: Although children with post-traumatic stress disorder (PTSD) and attention deficit hyperactivity disorder (ADHD) share a number of symptoms, differences in underlying biological arousal mechanisms are postulated, with hyperarousal characteristic of PTSD and hypoarousal characteristic of ADHD. Two measures of attentional regulation: a continuous performance task (Vigil), using both cued (AK) and uncued (K) conditions, and the Comali-Kaplan Stroop Test, were administered to three groups of boys, ages 9-12, all scoring intellectually within the average range on the K-BIT: (a) boys who met DSM-IV criteria for ADHD (b) boys who met DSM-IV criteria for PTSD and (c) a control group of boys with no psychiatric diagnosis. There were 15 participants in each group (n=45). Using response times and errors of commission and omission on the CPT, and time to complete each of three conditions on the Stroop as dependent measures, results showed no significant differences between the ADHD and the PTSD groups on any of the variables. The ADHD group made significantly more errors of omission and commission than the control subjects, while the PTSD group differed from controls in the number of commission errors only. Cueing on Vigil produced the expected main effect but did not interact with group. **Key words:** Attention, inhibition, Post-traumatic stress disorder, ADHD

Diferencias en la ejecución de niños con síndrome de estrés post-traumático, trastorno por déficit de atención con hiperactividad y grupo control en tests de atención e inhibición

Resumen A pesar de que los niños con síndrome de estrés post-traumático (SEPT) y trastorno de déficit de atención e hiperactividad (TDA-H) manifiestan síntomas en común, se proponen diferencias en los mecanismos biológicos subyacentes en los estados de alerta, con características de un estado hiperalerta en el SEPT y de un estado hipoalerta en el TDA-H. Se administraron dos medidas de regulación de la atención: una tarea de atención sostenida (Vigil), utilizando tanto una condición con antelación (AK), como sin antelación (K), y la prueba Stroop de Comali-Kaplan, a tres grupos de niños: un grupo llenaba requisitos del DSM-IV para el

diagnóstico de TDA-H, otro para el de SEPT, y un grupo control no tenía diagnóstico psiquiátrico. Hubo 15 participantes en cada grupo (N=45), con edades entre los 9 y 12 años, y con cociente intelectual en el K-BIT dentro del rango normal. Los resultados no arrojaron diferencias entre el grupo de TDA-H o el de SEPT en ninguna de las variables dependientes utilizadas: tiempos de respuesta y errores de omisión y comisión en la tarea de atención sostenida, así como tiempo para completar las tareas de la prueba Stroop. El grupo con TDA-H cometió más errores de omisión y comisión que el grupo control, mientras que el grupo con SEPT se distinguió del grupo control sólo en los errores de comisión. La antelación en Vigil produjo el efecto principal esperado, pero no mostró interacción con el factor grupo. **Palabras clave:** atención, inhibición, síndrome de estrés post-traumático, trastorno por déficit de atención con hiperactividad.

Both attention deficit hyperactivity disorder (ADHD) and post-traumatic stress disorder (PTSD) are thought to involve dysregulation of the arousal / attentional system. ADHD is the most commonly diagnosed neuropsychiatric disorder in children, and accounts for the largest number of referrals for mental health treatment (Richters, Arnold, Jensen, et al., 1995). Prevalence has been estimated to range between 1 and 18% worldwide, depending on diagnostic criteria and populations sampled (Jensen, 1999; Bird, 1996). While the specific features and etiology of the disorder continues to be the subject of debate, there is general agreement that the disorder is characterized by difficulties in attention, impulsivity, and hyperactivity (Solanto, 2001).

According to criteria from the Diagnostic and Statistical Manual Fourth Edition Revised (DSM-IV-R) of the American Psychiatric Association, the diagnosis is not made if the symptoms can be better accounted for by another mental disorder (e.g., a mood disorder or anxiety disorder). On the other hand, it is also indicated that when two disorders co-exist, each should be diagnosed. Thus, high rates of comorbidity have been recorded for ADHD and a variety of other disorders including oppositional defiant disorder (30 – 50%), anxiety disorders (25%), and mood disorders (15 – 75%) (Solanto, 2001).

Inevitably, some disorders that may co-exist with ADHD overlap in symptoms, raising important questions about etiology and diagnosis of comorbidity and its implications for treatment (see Marks, Newcorn, and Halperin, 2001, for a review of these issues). As expected, discussions of comorbidity have focused on disorders that are typically thought to result from genetic predisposition (e.g., mood, anxiety, and conduct disorders), with particular interest in the higher than expected rates of comorbidity of such disorders with ADHD, and their possible additive or multiplicative effects on behavior (Solanto, 2001; Armengol, in submission). Another

concern to the practicing clinician is that of pseudo-comorbidity due to symptom overlap, which may result in misdiagnosis when one condition is mistaken for another. Misdiagnosis has significant implications for treatment (Tannock, Ickowicz, and Schachar, 1995; Weinstein, Staffelbach, and Biaggio, 2000).

One condition that risks misdiagnosis, especially in children, is post-traumatic stress disorder (PTSD). According to the DSM-IV-R, PTSD is diagnosed when a person has experienced a traumatic event that involved actual or threatened death or serious injury, or a threat to the physical integrity of self or others, and the person's response involved intense fear, helplessness, or horror. In children, this may be expressed instead by disorganized or agitated behavior. Furthermore, the traumatic event is persistently re-experienced in one or more ways, and may involve physiological reactivity on exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event. There is avoidance of stimuli associated with the traumatic event, and, importantly from the perspective of this study, persistent symptoms of increased arousal, as indicated by two of the following: difficulty falling or staying asleep; irritability or outbursts of anger; difficulty concentrating; and exaggerated startle response. Finally, the disturbance lasts more than a month, and causes clinically significant distress or impairment in functioning.

Disorders of sleep are common to both PTSD and to ADHD (Glod and Teicher, 1996; Brown and McCullen, 2001), and are likely to affect daytime patterns of arousal. As noted by Glod and Teicher (1996, P.1385), "PTSD in childhood may …lead to behavioral problems that can resemble ADHD. Difficulty concentrating and diminished patterns of interest in activities found in PTSD could adversely affect academic performance and appear as inattention. A persistent state of hyperarousal could resemble hyperactivity, especially in a younger child." This presents potentially serious challenges to the diagnostic clinician, although careful assessment and history taking may do much to overcome possible confusion due to such mimicking of ADHD symptoms by another disorder. To complicate the matter further, high rates of comorbid ADHD have been reported for children with PTSD. In one study (Glodd and Teicher, 1996) 23% of children with PTSD were reported to have symptoms consistent with ADHD. In an earlier study by McLeer, Callahan, Henry, and Wallen (1994), 46% of the sexually abused children in their sample met criteria for ADHD. Given the overlap in symptoms described above, this does not seem surprising.

Nonetheless, even though these children may present with similar behavioral manifestations, various researchers have argued that the physiological underpinning is quite different for each disorder. In the case of

PTSD, the underlying abnormality is thought to be hyperarousal, resulting in symptoms of hypervigilance, increased startle reflex, affective lability, anxiety, dysphoria, and attentional difficulties (Perry and Pate, 1994; Van der Kolk and Saporta, 1991, Wolfe and Charney, 1991). In ADHD the underlying deficit is variously conceived as either hypoarousal (poor tonic arousal, or degree of wakefulness, due to abnormalities of the reticular activating system, or RAS), or more recently, hypoarousal of the inhibitory system, most likely associated with orbitofrontal cortex and the basal ganglia, in the context of normal tonic arousal but impaired phasic arousal (Arnsten, 2001; Solanto, 2001, Grace, 2001; Taylor and Jentsch, 2001, Castellanos, 2001).

Specific catecholamines including norepinephrine, dopamine, and acetylcholine are involved in the maintenance of vigilance (Weinberg and Harper, 1993). Depletion of these catecholamines in the brain is associated with lower levels of vigilance and has been associated with ADHD (Koziol and Stout, 1993; Posner, 1992; Weinberg and Harper, 1993). Robbins and Everitt (1995) argue that *reductions* in norepinephrine (NE) result in deficits in phasic alertness, or the ability to differentiate relevant from non-relevant stimuli, and thus make effective use of cues. Posner (1992) also postulated that depletion of NE, the fibers for which are predominantly distributed in the right frontal lobe, results in a deficit in the ability to alert oneself and to utilize warning cues, and saw this as characteristic of children with attention deficit disorder.

Neurobiological theories have also emphasized abnormalities in the noradrenergic system in response to stress (e.g., Robbins and Everitt, 1995; Gray, 1982) A *higher* than normal level of noradrenaline and other catecholamines is associated with hyperarousal difficulties, such as sleep disorders, hypervigilance, and increased anxiety. Abnormally high levels of these catecholamines have been found in patients with PTSD (Southwick, Bremner, Krystal, and Charney, 1994; Trickett and Putnam, 1994). In the case of PTSD, the most commonly hypothesized mechanism underlying performance deficits is over-stimulation of the NE network, resulting in up-regulation of NE turnover, which in turn disrupts performance on phasic arousal tasks (Arnsten, 2001).

McFarlane, Weber, and Clark (1993) studied event-related potential (ERP) indices of 18 PTSD patients and 20 controls while they performed a continuous performance (CPT) task, which consisted of detecting infrequent tones from a background sequence of frequent and infrequent distractor tones. They found delayed N2 and attenuated P3 waves, and noted that "…patients had abnormal difficulty distinguishing task stimuli of different relevance." Vasterling, Brailey, Constans, and Sutker (1998) hypothesized ,

based on prior research, that autonomic arousal would be disrupted in PTSD veterans, and more specifically that number of false positive (commission errors) would increase on a vigilance task in this population. Although they only examined responses to the cued condition of the Conner's CPT (which requires subjects to respond to all but the cued target letter), they found that the veterans with PTSD made more errors of commission than control subjects, but not more errors of omission. Unfortunately they did not test the subjects in the uncued condition, which would have provided an index of tonic arousal, nor did they analyze for possible differences in response time.

Vasterling and her colleagues found no difference between the groups on the Stroop Test Interference condition, which required participants to name the ink color in which discrepant color words were printed (thus inhibiting the more rapidly processed words). However, in another study (Beers and de Bellis, 2002), significant differences were found in the number of words completed on the Stroop Color Word Interference condition between 14 children with PTSD and 15 demographically similar children without PTSD.

Accordingly, in this study, the performance of children with ADHD and of children with documented PTSD and no ADHD were compared to that of non-clinical, healthy controls on a vigilance task that was designed to elicit performance on both a cued and an uncued condition. It was hypothesized that hyperarousal in the PTSD children would result in faster reaction times on both conditions and in an increase in commission errors relative to the normal controls. It was further hypothesized that ADHD children would demonstrate slower reaction times than the children with PTSD and controls, and make more errors of omission than the PTSD group and normal controls. Based on results from empirical studies to date, both clinical groups were expected to demonstrate elevated levels of commission errors. On the Stroop task, it was predicted that the PTSD and ADHD children would take longer to complete the interference condition than the controls.

Method

Participants

Forty-five boys (ages 9-12) from the greater Boston area participated. The age range was chosen to ensure that all subjects would meet minimum age requirements of the DSM-IV for the ADHD diagnosis. The ceiling was chosen in order to control for the impact of the changes of adolescence. In order to control for variability by sex only males were used, as research

indicates that ADHD is more prevalent in boys 3:1 in the community and 6:1 in the clinics (Slap-Shelton, 1994).

Participants were selected according to three mutually exclusive criteria and were placed in one of three groups according to the following: (a) boys who meet DSM-IV criteria for ADHD with no known history of trauma, (b) boys who meet DSM-IV criteria for PTSD, and (c) a control group of boys with no psychiatric diagnosis. Each group consisted of 15 boys.

Clinical participants were recruited from a local community mental health center and an inpatient, short term, psychiatric evaluation center, and the control group was selected from children in the community. For the clinical group, directors of each program contacted were given information regarding criteria for participation. Referrals were selected on the basis of diagnoses given to them by the clinicians at that facility. Clinicians and guardians were then asked to confirm diagnoses by checking off criteria set forth by the DSM-IV for ADHD or PTSD, as well as by completing the PTSD portion of the ADIS-C (see below).

In the final sample, the PTSD group was composed of eight boys drawn from the residential treatment facility, and seven from the community mental health center. In the ADHD group twelve boys were selected from referrals by the community mental health center, and three from direct referrals to one of the authors. The control group came from responses of community dwellers to a request for volunteers by one of the authors (AC-S). None of the children fell in the borderline or mentally retarded category, based on scores on the K-BIT. Demographic data is provided in Table I for all three groups.

	PTSD n=15	ADHD n=15	Control n=15	p
Age	10.27 (1.03)	10.53 (1.25)	10.47 (.99)	.787
K-BIT IQ	88.6 (8.36)	92.13 (9.39)	97.67 (7.59)	.020

Table 1. *Age and IQ for ADHD, PTSD and Controls*

Instruments

Two rating clinical scales to assist in confirming the clinical diagnoses (the PTSD scale of the ADIS-C and the Conner's Rating Scale), a brief test of intellectual functioning (the K-BIT, Kaufmann & Kaufmann, 1990), and two neuropsychological measures of sustained attention (Vigil Continuous Peformance Task, Cegalis, 1991), and the Stroop Test (Kaplan, cited in Mitrushina, Boone, & d'Elia, 1999) were utilized. A description of each follows.

Anxiety Disorders and Interview Schedule for Children (ADIS-C). This instrument is designed to aid in distinguishing among the various anxiety disorders of the DSM-IV. The ADIS-C also includes sections for assessing mood and externalizing disorders so that possible comorbid disorders can also be evaluated (Albano and Silverman, 1996). The ADIS-C is used for children ages 7-17 and consists of semi-structured interview schedules for both the parent and child. For the purposes of this study only the PTSD scale of the ADIS-C were given.

The Child Interview section of the ADIS-C begins with a school history, and continues with specific questions related to each anxiety disorder in the following order: Separation Anxiety, Social Phobia, Specific Phobia, Panic Disorder, Agoraphobia, Generalized Anxiety Disorder, Obsessive-Compulsive Disorder, and Post traumatic Stress Disorder/Acute Stress Disorder. Following this section the ADIS-C assesses the child for the possibility of co-morbid affective disorders and externalizing disorders (i.e. dysthymia, ADHD). Additional screening questions related to possible secondary disorders then follow (i.e. substance abuse, schizophrenia, eating disorders, etc.). This section is not used in making a definitive diagnosis but rather to highlight additional areas of potential concern. The Parent Interview Schedule is similar to the format of the Child Interview Schedule, but is more detailed in its questions about school history and consequences (Albano and Silverman, 1996).

Conner's ADHD Scale (Conner's 1989). Both the Parents' and Teacher's scales comprise statements containing problem behaviors in the child. Ratings are coded 0 (not at all), 1 (just a little), 2 (pretty much), or 3 (very much). There are extended and brief forms of these scales. For the purpose of this study the brief scales, which are commonly used, were utilized. The Parent Rating Scales (CPRS-48) have 48 items and yield 6 indices: conduct problem, learning problem, psychosomatic, impulsive, hyperactive, anxiety, and a 10-item hyperactivity index. The Teachers' Rating Scales (CTRS-28) contain 24 items and yield 4 indices: conduct problem, hyperactivity,

inattentive-passive, and a 10-item hyperactivity index. These scales are widely used throughout the world and numerous validation and normative data have been collected on them.

Kaufmann Brief Intelligence Test (K-BIT, Kaufmann & Kaufmann,1990). This is a brief intelligence test that assesses verbal and non-verbal factors and provides an overall measure of IQ (the K-BIT Composite Score), also yielding standard scores for Vocabulary and Matrices. The task was administered to control for I.Q; only those subjects with IQ's in the average range (between 85 and 115) participated in the study to avoid the confound of the possible effects of below average or superior intellectual functioning.

Vigil Continuous Performance Test (Cegalis, 1991, now available through The Psychological Corporation) – Modeled after the test originally devised by Rosvold in 1956, this task includes two conditions: cued with and without interference, and uncued with and without interference. In this study all participants were been tested under two standard conditions, K and AK. In the K (uncued) condition, children were asked to press a key on the computer keyboard each time the letter K appeared but not when other, letters are sequentially presented in random order. Stimuli are presented in white on a black background, using the installed Vigil stick font, for a period of 85 msec., with an interstimulus interval of 900 msec, over 4 trial blocks of 120 stimuli each, with 36 targets per block. In the AK (cued) condition, children were asked to respond to the letter K only when preceded by an A. Standard instructions provided in the manual were followed in the administration of each condition; in the case of the cued condition no information regarding the probability that a target would follow a cue was provided. Each condition lasted eight minutes. The two conditions were presented such that the uncued condition always preceded the cued condition.

Comali- Kaplan Stroop Test - Based on the original work of Stroop (1935), who demonstrated that the time it takes to name colors or to read color words is significantly faster than the time it takes to read color words printed in discrepant color, the Stroop test, in its various clinical forms (c.f., MacLeod, 1991; Jensen & Rohwer, 1966; Mitrushuina, Boone, & d'Elia, 1999) has been widely researched and shown to be a useful measure of the ability to inhibit automatized responses, and to maintain focus in the presence of distraction (Mitrushina, Boone, & D'Elia, 1999).

In this study the Comali-Kaplan version (Mitrushina et al., 1999) was utilized. The stimuli consisted of three 24 X 24 cm. while cards, each containing 100-items (10x10). The first card contained patches of the colors red, blue, and green randomly selected and arranged in rows. The second card contained the printed name of those colors. The third consisted of the

same color words printed in a discrepant ink color. Dimensions of individual items (whether color patches or words) were 4 X 8 mm. Words were printed in capital letters, in 12 pt. Times New Roman font. A hand-held stopwatch was used to record time to completion of each condition. The number of uncorrected and self-corrected errors was also noted on response forms.

Procedure

Clinicians were asked to complete a checklist indicating which symptoms were used in making the psychiatric diagnosis and to ensure that the DSM-IV criteria for each subject was met. Boys with ADHD who through an initial description by clinicians were reported to have a history of trauma were excluded from the study, as were boys with PTSD who also were reported to carry a diagnosis of ADHD.

Each parent/guardian was then provided with an informed consent form one week prior to any testing so that potential participants would have a chance to examine and sign it before beginning any testing. All participants/guardians then signed the consent form if they agree to participate. Parents or guardians, as well as clinicians were then asked to complete the PTSD scale of the ADIS-C and the Conner's ADHD Inventory. In situations were parents were not available and guardians (Massachusetts Department of Social Service case workers) had limited knowledge of a child's day to day behavior (i.e. a child was in a residential setting) therapists and childcare workers were asked to complete the scales.

The investigator then scheduled an assessment appointment, where the Kaufman Brief Intelligence Test (K-BIT), the VIGIL, the Stroop were individually administered, in the same order, to all selected participants. Procedures were completed in one assessment session, which lasted approximately one hour.

Results

On the Vigil continuous performance task, no differences in reaction time between the three groups were obtained for either the uncued (F: 2, 24 = 1.021, p=.369) or cued conditions (F: 2. 24 = 1.41, p= .256). Analysis of variance using errors of commission and omission as dependent variables did, however, show some differences between the clinical and control groups.

A repeated measures analysis of variance for errors of omission, with the cued and uncued conditions as the within subjects factor, and ADHD, PTSD, and control groups as the between subjects factor revealed no interaction, but significant main effects for cueing (F: 2,42 = 18.453, p= .0001) and group (F: 2,42 = 7.134, p = .002) were found. There were fewer mean omissions for the cued condition (M=13.75, SD=11.6) compared to the uncued condition (M=25.07, SD=19.6). This result is consistently found in the literature. i.e., facilitation of target identification due to cueing.

Regarding the main effect of group, post-hoc analysis using Tukey's HSD indicated that the PTSD group did not differ in number of omission errors (M = 20.3) from either the ADHD (M = 27.4) or control (M = 10.9) group. The ADHD group, however, missed significantly more targets than the control group.

A 2-way ANOVA was also conducted using errors of commission (false alarms) as the dependent measure, with groups as the between-subjects and cueing as the within-subjects factor. No significant interaction or cueing effects were obtained, but a group main effect was significant (F: 2,46= 4.66, p=.015). A post-hoc analysis using Tukey's HSD indicated that both clinical groups made significantly more commission errors than the control group, but did not differ from each other.

On the Comali-Kaplan Stroop Test, one way analysis of variance of group by condition with reaction time as the dependent measure revealed no differences for either the color naming (F: 2, 24 = 2.18, p=.13) or interference conditions (F: 2, 24 = .410, p = .67) for the three groups. Word reading was, however, significant (F: 2,42 = 4.00, p=.03), showing an advantage in speed of completion for the control group, which was faster (M = 45) than the PTSD (M = 76.52) group. The ADHD group did not differ significantly from either group on speed of word reading.

Discussion

Results are consistent with the hypothesis that children with PTSD would make more errors of commission than normal controls, but an equal number of omission errors. The hypothesis that the ADHD group would make significantly more errors of omission than controls was also confirmed. Both clinical groups made more errors of commission than the control group. Thus the PTSD group differed from controls on errors of commission only, while the ADHD group differed from controls on number of omission and commission errors.

The hypothesis that hyperarousal (in the PTSD group) would result in faster reaction times than the other two groups on both uncued (tonic arousal) and cued (phasic arousal) conditions was not supported. The hypothesis that children with ADHD would be slower also did not receive support. These results are inconsistent with previous studies (e.g., Riordan et al, 1999; Armengol, submitted) that found motor slowing in adult ADHD groups on phasic cueing conditions. One difference between those studies and this one is the age of the subjects. This may have affected results to the extent that the children in all groups were extremely variable on RT, and this heightened variability may have masked any differences between the groups. Replication studies with a larger number of children may be able to capture any existing effect. The results indicate that error patterns are more sensitive to differences between the groups than response times.

The absence of an interaction between cueing condition and group on the error analysis indicates that, while all groups showed differences between cued and uncued conditions, no group benefited more or did worse than the other groups under conditions of phasic versus tonic arousal. This is also inconsistent with previous findings in adults (Armengol, submitted), where differences in error patterns were observed across cued versus uncued conditions, such that ADHD subjects consistently showed worse performance on the phasic (cued) condition. Given the dearth of studies that have examined the issue of tonic versus phasic arousal and the implications for medication, replication studies are clearly indicated to determine whether the differences observed between children and adults is due to developmental differences or not.

A similar issue arises in the case of the Stroop test, where previous research with PTSD adults failed to find differences, while a study with children with PTSD (Beers and DeBliss, 2002) did find differences. This study, while employing a different version of the Stroop, failed to replicate the earlier findings with children. Further research is needed to determine whether these differences across studies were due to differences in procedure or populations sampled.

In summary, results from the current study indicate that when a child has a significantly higher number of commission errors, but errors of omission are within the normal range, the child is more likely to have a diagnosis of PTSD. However, when a child has more errors of both omission and commission compared to normative data, the child is more likely to have a diagnosis of ADHD.

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