RUNNING HEAD: ADHD, creativity, behavior and cognitive functioning.

# An investigation into the relationship among ADHD symptomatology, creativity, and neuropsychological functioning in children.

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Abstract

This paper examined the relationship between creativity and ADHD symptomatology. First, the presence of ADHD symptomatology within a creative sample was explored. Secondly, the relationship between cognitive functioning and ADHD symptomatology was examined by comparing four groups, aged 10-12 years: 1) 29 ADHD children without creativity, 2) 12 creative children with ADHD symptomatology, 3) 18 creative children without ADHD symptomatology, and 4) 30 controls. Creativity, intelligence, processing speed, reaction time, working memory, and inhibitory control were measured. Results showed that 40% of the creative children displayed clinically elevated levels of ADHD symptomatology, but none met full criteria for ADHD. With regard to cognitive functioning, both ADHD and creative children with ADHD symptoms had deficits in naming speed, processing speed, and reaction time. For all other cognitive measures the creative group with ADHD symptoms outperformed the ADHD group. These findings have implications for the development and management of creative children.

**Key words:** ADHD, creativity, behavior and cognitive functioning.

# An investigation into the relationship among ADHD symptomatology, creativity, and neuropsychological functioning in children.

Both creativity and Attention-Deficit/Hyperactivity Disorder (ADHD) are extensively studied topics in child psychology. There is much debate over how best to define each construct and in addition, some authors have argued that there are distinct similarities between the two (e.g., Cramond, 1994b; Leroux & Levitt-Perlman, 2000). These authors are concerned about the similarities and advocate for better ways to discriminate between the two, so that teaching can be adapted accordingly and development is not hindered by unnecessary medication of misdiagnosed children. They argue that the way one would treat a highly creative child should be very different from that of an ADHD child. With regard to the similarities in behavior, Dawson (1997) found that teachers rated the following traits as typical of a creative child: "makes up the rules as he or she goes along," "is impulsive," "is a nonconformist," and "is emotional." Similar teacher ratings such as "defies or refuses teachers' requests or rules," "impulsive or acts without thinking" and "stubborn, sullen, or irritable" have been used to describe children with ADHD (Skansgaard & Burns, 1998).

Very few studies have empirically investigated the relationship between ADHD and creativity. Cramond (1994a) found that in a sample of 76 creative adolescents, 26 percent of them met self reported clinically elevated symptoms of ADHD. Thus the descriptions of the behavior of highly creative children, along with Cramond's (1994a) findings, suggest that ADHD and some creative children can display very similar behaviors. What is still unknown is whether different etiological factors are likely to lead to similar behaviors, or whether the same underlying mechanisms are responsible.

To date, the most prominent theory of ADHD suggests that self-regulation underlies the deficits seen in cognitive and behavioral functioning in ADHD (Barkley, 1997). This idea has been supported by research findings that children with ADHD have mild deficits in working memory and motor responses (Tannock, 1998), have difficulties inhibiting or delaying behavioral responses (Nigg, 1999) and are much slower at processing simple information (Rucklidge & Tannock, 2002).

Unlike ADHD, the literature on the cognitive functioning of highly creative children is sparse with little consensus emerging, thus it is difficult to ascertain whether similar cognitive deficits may underlie the similar behaviors seen in ADHD and creative children. In relation to the cognitive functioning of creative individuals, Stavridou and Furnham (1996) and Green and Williams (1999), found that individuals with high divergent thinking ability had intact inhibition skills. Further, Gamble and Kellner (1968) and Golden (1975) found that creative individuals were less susceptible to interference than non-creative individuals, as measured by the Stroop task. On the other hand, Carson, Peterson and Higgins (2003) found that highly creative individuals had lower scores on a measure of latent inhibition, the ability to filter out both internal and external stimuli previously experienced as irrelevant. They argued that it is this inability to filter out information, in combination with high IQ, which makes these individuals constantly open to much more information, increasing the chances of them coming up with an original recombination of information. This idea has been expressed by a number of creativity theorists who argue that attention to a wide array of stimuli allows an individual to consider possibilities that they may miss if they had a more narrow focus (e.g., Eysenk, 1999; Wallach, 1970). Thus creative children may experience similar cognitive deficits to those found in children with ADHD.

Given the lack of empirical literature to date, the first aim for this study was to examine the prevalence of clinically elevated ratings of ADHD symptomatology in a creative population first via parent report rating scales and then second via a standardized clinical interview to more specifically describe the ADHD symptoms in the creative population. The second aim was to compare four groups on neurocognitive functioning: 1) children diagnosed with ADHD with normal levels of creativity, 2) creative children with ADHD symptoms, 3) creative children without ADHD symptoms, and 4) a normal control group, in order to assess whether the presence of ADHD symptomatology in creative children affects their cognitive functioning in ways similar to those displayed by ADHD children. The hypotheses for the study were that a significant number of creative children will display symptoms of ADHD and that despite their creativity, these children will display similar cognitive deficits to children diagnosed with ADHD.

*Participants*

Eighty-nine children aged between 10 and 12 years old took part in the study: 1) 29 (21 male, 8 female) were diagnosed with any of the three types of ADHD (predominantly inattentive, hyperactive and combined type) and had normal creativity scores on the Torrance Tests of Creative Thinking (TTCT – see below), 30 (14 male, 16 female) were identified as highly creative and divided into two subgroups with and without ADHD symptomatology (see below), and 30 (13 male, 17 female) normal controls with no indication of ADHD or creativity. Participants were predominantly Caucasian of varying S.E.S. backgrounds, residing in Christchurch, New Zealand. Recruitment was conducted through advertisements in local newspapers, gifted classes, school notices, and an ADD support group newsletter.

*Inclusion criteria for the ADHD group:* This group was established by confirming that all children had received a prior diagnosis of ADHD from either a psychiatrist or registered psychologist before entering the study, and that they had TTCT scores below the 90$^{th}$ percentile. This latter inclusion criterion was necessary in order to eliminate the possibly confounding effect of creativity on the neurocognitive functioning of the ADHD children. *T*-scores of 65 or above on the DSM-IV inattentive, DSM IV hyperactive-impulsive, and/or DSM IV total subscales of the long versions of the parent form of the Conners' Rating Scales-Revised (CPRS-R; Conners, 1997 – see below) were used to confirm ADHD diagnosis. While data was collected on the teacher form of the Conners' (CTRS-R), this data was not used for classification purposes given that 26 of the ADHD children were on stimulant medications and therefore behavioral ratings in the classroom would likely underestimate ADHD symptoms. Further, recent work by Biederman, Faraone, Monateaux and Grossbard (2004) demonstrated that parents can be accurate reporters of ADHD symptoms and therefore it was deemed that these parent reports, along with a diagnosis from a clinician, was sufficient for inclusion in the ADHD group. Four children recruited for their ADHD diagnosis were excluded from the study due to their high TTCT scores (i.e. above 90$^{th}$ percentile).

In order to best explore the relationship between ADHD and creativity, two subgroups of the creative children were formed: a creative group with ADHD symptoms (CA) and a creative group without ADHD symptoms (CNA). *Inclusion criteria for the CA group:* Those children who scored in the 90$^{th}$ percentile or higher on the TTCT, and also had *T*-scores of 65 or above on the DSM-IV inattentive, DSM IV hyperactive-impulsive, and/or DSM IV total subscales of CPRS-R were included. A formal diagnosis of ADHD was not required for inclusion in this group as the aim of the study was to investigate those children exhibiting clinically impairing symptoms of ADHD in addition to being creative; excluding those not meeting full criteria would potentially eliminate those creative children driving the controversy between ADHD and creativity. *Inclusion criteria for the CNA group:* This group was established by confirming that each child scored in the 90$^{th}$ percentile, or higher, on the TTCT and had *T*-scores below 60 on the CPRS-R.

*Inclusion criteria for the control group (NC)*: All the control children had *T*-scores below 60 on CPRS–R, and TTCT scores below the 90$^{th}$ percentile.

*Exclusion criteria for all groups:* Individuals with an estimated IQ score below 80, English as a second language, uncorrected problems in vision or hearing, serious medical problems, or serious psychopathology were excluded. These criteria did not result in the exclusion of any participants.

*Measures of ADHD symptomatology*

Long versions of the parent (CPRS-R) and teacher (CTRS-R) forms of the Conners' Rating Scales-Revised (Conners, 1997) were used to measure ADHD symptomatology. The reliabilities across forms and raters are in the .85 to .95 range. Test-retest reliabilities at 6 to 8 weeks average .70 for the long version forms (Reitman, Hummel, Franz, & Gross, 1998).

As none of the creative children had been diagnosed with ADHD, the parents of all creative children who received *T*-scores above 65 (clinical cut off) on the DSM-IV inattentive, DSM IV hyperactive-impulsive, and/or DSM IV total subscales of the CPRS-R or CTRS-R, were interviewed by a doctorate level clinical psychologist using the behavioral section of the Schedule for Affective Disorders and Schizophrenia for school age children – Present and Lifetime Version (K-SADS-PL, Kaufman, Birmaher, Brent, Rao & Ryan, 1996), in order to further explore and describe the extent of ADHD symptomatology in the creative children. This interview generates DSM-IV diagnoses, and was used to determine whether or not these children met full criteria for a diagnosis of ADHD. The instrument has been validated with children aged 6 to 17 (Kaufman et. al., 1997). While this interview was not used for classification purposes, it was conducted in order to more accurately document the difficulties the creative children were having in the areas of attention, activity and impulsivity.

*Measure of Creativity*

*Torrance Tests of Creative Thinking:* Creative potential was measured using the TTCT, Figural Form A (Torrance, 1998) which is made up of three tasks, all of which involve coming up with unusual drawings that have standard shapes (e.g. a pair of straight lines) as a part of them. Each drawing is scored on 5 subscales: originality, fluency, elaboration, abstractness of titles, and resistance to premature closure. The final percentile ranking is based on a combination of the scores for the 5 subscales as well as additional aspects like humour, emotional expressiveness, and richness of imagery. The inter-rater reliability of this measure is high, with correlations generally above .90 (Torrance, 1998). Torrance (1981) conducted a 22 year longitudinal study on the predictive validity of this measure, which compared scores from various forms of the TTCT with later life creative achievements. An overall creativity index score was devised based on participants' performance on the creativity tests. The creativity index was correlated with five indices of creative achievement and the product moment correlation coefficients were all significant at the 0.001 level. These indices included: number of high school creative achievements ($r = 0.38$), number of post high school creative achievements ($r = 0.46$), number of creative style of living achievements ($r = 0.47$), quality of highest creative achievements ($r = 0.58$), and quality of future career image ($r = 0.57$).

*Measure of Socioeconomic Status*

Socioeconomic status (SES) was determined using the New Zealand Socioeconomic Index of Occupational Status (NZSEI), an index which assigns New Zealand occupations with a socioeconomic score (Davis, McLeod, Ransom & Ongley, 1997). Scores range from 10 (low SES) to 90 (high SES).

*Measure of Intelligence*

*Wechsler Intelligence Scale for Children:* IQ was estimated using the Block Design and Vocabulary subtests of the WISC-III (Wechsler, 1991), which when combined are good indicators of Full Scale IQ (Sattler, 2002). The results of these subsets correlate highly with the full WISC III test, with $r = .862$ (Sattler, 2002).

*Measure of Working Memory*

*Wechsler Intelligence Scale for Children:* Working memory was measured using the Digit Span and Arithmetic subtests and the Freedom from Distractability index score of the WISC-III (Wechsler, 1991).

*Measures of Processing and Naming Speed*

*Wechsler Intelligence Scale for Children:* Processing speed was measured using the Coding and Symbol search subtests and the Processing Speed index score of the WISC-III (Wechsler, 1991).

*Rapid Automatized Naming:* Four tests of Rapid Automatized Naming (RAN) were selected: letter, number, colour, and object. RAN-Letters consists of 5 lower case letters repeated 10 times in random sequence, yielding 50 stimuli presented in 5 rows of 10 items on a chart. With an identical lay out to RAN-Letters, RAN-Numbers consists of 5 digits, RAN-Colours consists of 5 colour blocks, and RAN-Objects consists of 5 objects. Total time taken (in seconds) to name all stimulus items on each chart were the dependent variables. Number stated correctly, number of omissions, additions, deletions, and errors were also assessed as control variables. ADHD children have been found to be impaired on all of the tests chosen (see Rucklidge & Tannock, 2002).

*Measures of Reaction Time and Inhibitory Control*

*Stop Task:* The Stop task tracking version (Williams, Ponesse, Schacher, Logan, & Tannock, 1999), a variant of the stop-signal paradigm (Logan, 1994), was used to measure reaction time and the degree of voluntary inhibitory control that participants can exert over response processes. The paradigm involves two concurrent tasks, a ‘go’ task and a ‘stop’ task. The go-task is a choice reaction time task that requires the individual to discriminate between X and O by pressing the associated buttons on a separate response box. The stop-task (which occurs on 25% of the go-task trials) involves the presentation of a tone that informs the individual to stop (inhibit) his/her response to the go-task for that trial. Dependent measures are the latency and variability of responses to the go-task and estimated stop-signal reaction time.

*Stroop Task:* Inhibitory control and naming speed were tested using the Stroop Task (Golden, 1978). There are three parts to the test: the first involves participants reading randomised colour names (blue, green, red, yellow) printed in black type, in the second part the participant has to name the colour of the printed crosses, and the third part involves participants reading the colour names printed in coloured ink of a different colour to the colour-word. Number of items identified correctly are recorded in order to determine the amount of interference encountered. Test-retest reliability was calculated using a one-month between test sessions, and it reliability estimates of .90, .91, and .83 were found for the three parts of the test (Spreen & Strauss, 1991).

*Stroop Negative Priming Task:* Reaction time, number of errors and negative priming were measured using this variant of the Stroop task (Pritchard & Neuman, 2004). This task involves reading out 16 cards which have 11 colour words printed in incongruent colours, on each card. Each word and each ink colour appeared only once on a given card. Test cards consisted of six Unrelated (UR) trials (where neither the hue nor distractor colour-word in a stimulus were repeated in the subsequent stimulus) and six Ignored Repetition (IR) trials (where the distractor word in a previous display repeated as the subsequent target hue) cards. Four additional UR cards were used for practice trials. The first two items on each IR card were unrelated in order to reduce the saliency of this condition. Time to read each card and number of errors was recorded.

*Measures of executive functioning*

*Tower of London:* Problem representation, planning, execution and evaluation were tested using the Tower of London task (TOL, Shallice, 1982). This task involves following certain rules to accomplish the goal of moving a set of blocks from one position to another.

Points are gained for correct solutions to the puzzle and time taken to make the first move is recorded as an indicator of time spent planning the exercise. Overall, this task appears to be a developmentally sensitive and neuropsychologically valid planning measure (Lyon, 1994). Only on very young children is a satisfactory test-retest reliability of 0.71 explicitly reported (Gnys & Willis, 1991).

*Maier's two-string problem:* Insight and abstractness of thinking were tested using Maier's two-string problem (Maier, 1931) which has been characterised as being high in novelty and having considerable ecological validity in being close to real life problems (Kaufman, 1979). For this task, two pieces of string were hung from the ceiling on either side of a room. The strings were not long enough to be able to hold one and reach to grab the other. The children were given a number of tools that they could use to help tie the strings together and were asked to think of as many different ways as they could to use the tools to tie the strings. The number of ideas (i.e. different ways to tie the strings together) was recorded as one measure. The particular idea of using one of the tools, a spanner, as a pendulum in order to tie the two strings together was scored as a separate measure, as use of this tool indicated a high level of abstract thinking ability.

*Procedure.*

Each child was tested individually for two and a half hours. Ethics approval for the study was gained from the local Human Ethics Committee. Participation was voluntary and included parental and child consent. Ninety percent (n=26) of the children diagnosed with ADHD were taking the short-acting form of methylphenidate as medication for the disorder and were asked not to take their medication 24 hours prior to the day of testing as stimulant medications are known to affect cognitive functioning (Berman, Douglas & Barr, 1999). On the day of testing, it was confirmed with parents that the child had not been given their ADHD medication. As methylphenidate has an approximate half-life of 4.5 hours (Shader, Harmatz, Oesterheld, Parmelee, Sallee, & Greenblatt, 1999), a 24 hour elimination period should have ensured that the majority of the active ingredient had been eliminated prior to testing. Parents and teachers were asked to fill in the CRS-R.

*Statistical Analyses*

Results were analysed using the Statistical Package for the Social Sciences- windows version 11.5. Univariate analyses of variance were used to examine group difference and if the overall Wilk's Lambda was significant ($p < 0.05$); specific group differences were examined with post-hoc Tukey tests using a $p$ value of .05. Cohen's $d$ effect size (ES) calculations were used to further determine the magnitude of the difference between the creative and ADHD groups.

## Results

*Sample characteristics.*

There were no group differences on age; however, there were group differences on SES, IQ, TTCT, and ADHD symptomatology (see Table 1). For SES, $F\ (3.88) = 13.02$, $p < 0.001$, the CA, CNA and NC groups' parents had higher ratings than ADHD group's parents. The estimated FSIQ scores of the CA and CNA groups were higher than those of the NC group, who in turn had higher IQ scores than the ADHD group, $F\ (3,88) = 11.83$, $p < 0.001$. Further, the correlation between IQ and creativity was examined and a significant positive relationship was found, $r = 0.47$, $p < 0.01$.

Not unexpectedly, the TTCT scores of the CA and CNA groups were higher than those of the ADHD and NC groups. There were no differences in the creative ability of the ADHD and NC groups, $F\ (3,88) = 39.04$, $p < 0.001$.

In relation to ADHD symptoms, 12 (40%) of the 30 creative children (9 male, 3 female) were rated by their parents as displaying significant levels of ADHD symptomatology (i.e. *T-scores* of 65 or above on the DSM-IV inattentive, DSM IV hyperactive-impulsive, and/or DSM

IV total subscales). Teacher ratings of their ADHD symptomatology, on the other hand, were not in the significant range. These lower teacher ratings could be due to the unique school environments (small classes, enriched and stimulating environments) many of the creative children were being taught in (Bussing, Gray, Leon, Wilson Garvan, & Reid, 2002). Overall, there was a large effect-size (by Cohen's convention) between both parent and teacher ratings of the CA and CNA groups (see Table 1). These 12 children were placed in the CA group and the other 18 placed in the CNA group.

The K-SADS-PL interview determined that 11 of the CA children had mainly inattentive symptoms and one had symptoms of both impulsivity/hyperactivity and inattention. On average, they displayed 3.5 of the nine inattentive symptoms (SD = 1.51) and 0.67 of the nine hyperactive/impulsive (SD = 1.23) symptoms of ADHD. None of the children met full criteria for a diagnosis of ADHD as they were not meeting the criteria of having six of the nine symptoms of ADHD. Further, even with those symptoms the children displayed, many parents indicated that the symptoms were not impairing them across multiple settings. On the Inattentive subscale of the CPRS-R, the CA group had higher scores than the CNA and NC groups, $F(3,88) = 116.68$, $p < 0.001$. On the Hyperactive, $F(3,88) = 132.11$, $p < 0.001$ and DSM IV-total, $F(3,88) = 227.483$, $p < 0.001$, subscales the ADHD group scored higher than the CA group who in turn scored higher than the CNA and NC group. For the CTRS-R, the ADHD and CA groups did not differ, and scored higher than the CNA and NC groups on the Inattentive subscale, $F(3,88) = 12.91$, $p < 0.001$. The ADHD group scored higher than the other three groups on the Hyperactive subscale, $F(3,88) = 10.01$, $p < 0.001$, and on the DSM-IV total subscale, $F(3,88) = 13.29$, $p < 0.001$ the ADHD group scored higher than the CNA and NC groups.

Insert Table 1 about here

*Covariates*

All of the univariate analyses reported in this study were rerun separately controlling for Estimated Full Scale IQ and SES as both of these dependent variables were significantly different across groups. Full Scale IQ was not used as a covariate for WISC III data. All but one of the significant group differences remained statistically significant after controlling for both IQ and SES. Only TOL points for correct solution became non- significant after controlling for IQ. No non-significant results became significant.

*Measures of Working Memory*

The ADHD group scored lower than all of the other groups on the Arithmetic subtest of the WISC III, $F$ (3,88) = 9.88, $p < 0.001$. For WISC III Digit Span, $F$ (3,88) = 6.97, $p < 0.001$, Raw Digit Forward, $F$ (3,88) = 2.87, $p < 0.05$, and Raw Digit Backward, $F$ (3,88) = 4.36, $p < 0.01$, the ADHD group scored lower than the CNA group. For Digit Span, the CNA group had higher scores than the NC group. For the Freedom from Distractibility index score of the WISC III, the ADHD group scored lower than all of the other three groups, and the CNA group had higher scores than the NC group, $F$ (3,88) = 12.72, $p < 0.001$ (see Table 2).

*Measures of Processing and Naming Speed*

The ADHD group scored lower than all the other groups on the Processing Speed subscale, $F$ (3,88) = 11.06, $p < 0.001$, and Symbol Search subtest, $F$ (3,88) = 5.78, $p < 0.01$, of the WISC-III. For Coding, $F$ (3,88) = 5.78, $p < 0.001$, they scored less than the CNA and NC groups. The CA group had lower scores than the CNA group on Coding.

On the RAN, the ADHD group were slower than the CNA and NC groups at reading out the cards for RAN-Letters ($F$ (3,88) = 4.73, $p< 0.01$), Colours ($F$ (3,88) = 7.21, $p< 0.001$), and Objects ($F$ (3,88) = 4.92, $p < 0.001$), and for RAN-Numbers ($F$ (3,88) = 4.88, $p < 0.01$) they were slower than the CNA group (see Table 2). ANOVAs were also conducted to see if there were any group differences on RAN number of omissions, additions, and deletions. No differences were found, suggesting that the slower responses in ADHD and CA were due to slower retrieval rather than mediated by inaccurate retrieval. Indeed the number of errors across the four tasks was less then one error for all groups which is to be expected given the simplicity of the task.

*Measures of Reaction Time and Inhibitory Control*

For the Stop task, the ADHD group showed more variability in their go-reaction times than all three other groups, $F$ (3,88) = 5.93, $p < 0.001$. They had slower stop-signal-go reaction times, $F$ (3,88) = 5.93, $p < 0.001$, and made more errors, $F$ (3,88) = 5.07, $p < 0.01$, than both the CNA and NC groups. There were no group differences for Stop go-reaction-time, $F$ (3,88) = 0.84, *ns* (see Table 2).

The ADHD group were also slower than the CNA and NC groups at reading out the cards for Stroop-Word ($F$ (3,88) = 9.89, $p < 0.001$), Colour ($F$ (3,88) = 8.44, $p < 0.001$), and Colourword ($F$ (3,88) = 7.61, $p < 0.001$). There were no group differences for Stroop interference ($F$ (3,88) = 1.03, *ns* (see Table 2).

For the Stroop Negative Priming Task, a two-way mixed analysis of variance (ANOVA) was carried out on the mean reaction times. The between-subjects factor was group (ADHD versus CA versus CNA versus NC) and the within-subjects factor was priming condition (Unrelated versus Ignored Repetition). The between-subjects factor of group was significant, $F$ (3, 86) = 8.34, $p < .001$. In order to determine whether there were differences in the overall reaction times between the groups, Newman-Keuls post-hoc analyses were conducted. The results indicated that the ADHD group responded significantly more slowly than both the CNA and control groups, ($p$'s < .01), but there was no difference between the ADHD and CA groups, and between both of the creative groups and the control group. The within-subjects factor of priming condition (Unrelated versus Ignored Repetition) was significant, $F$ (1,86) = 6.53, $p < .01$, and there was no interaction, $F < 1$. Thus, all participants responded slower on the Ignored

Repetition trials than on the Unrelated trials, showing that the NP effect was similar across the three groups and was unrelated to overall processing speed. Similar analyses were conducted for error scores. The between-subjects factor of group type was significant, $F$ (3,86) = 6.03, $p <$ .001. Newman-Keuls analyses indicated that the ADHD group made significantly more errors than the other three groups ($p$s < .01). No other error effects were significant. This shows that all of the groups produced numerically more errors in the Ignored Repetition than the Unrelated condition, therefore there is no indication of speed-accuracy trade-offs that could compromise the reaction time analyses.

*Measures of Executive Functioning*

For the TOL, the ADHD group came up with fewer correct solutions to the puzzle than both the CA and CNA groups, $F$ (3,88) = 3.70, $p < 0.05$. They also made their first move significantly faster than the CNA and NC groups showing that they were not taking as much time to plan their moves, $F$ (3,88) = 5.35, $p < 0.01$. Performance on the TOL was the only measure where the CA and CNA groups had similar scores and were clearly out performing the ADHD group (see Table 2).

For Maier's two-string problem, the ADHD group came up with fewer ideas than both the CA and CNA groups; and the NC group came up with fewer ideas than the CNA group, $F$ (3,88) = 9.58, $p < 0.001$. A chi square test was used to determine whether there were group differences in the number of children who thought to use the wrench as a pendulum in order to tie the pieces of string together, for Maier's two-string problem. A significant difference was found, $\chi^2$ (3, 89) = 24.858, $p < .001$. Twenty four percent ($n$ = 7) of the ADHD group, 83% ($n$ = 10) of the CA group, 61% ($n$ = 11) of the CNA group, and 20% ($n$ = 6) of the NC group thought to use the pendulum.

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Insert Table 2 about here

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*Effect Size Calculations*

Overall, effect size calculations for all neorocognitive functioning measures showed small to medium differences between the CA and ADHD groups and medium to large differences between the CA and CNA groups. By looking at the means and effect sizes of the ADHD, CA and CNA groups, it is clear that the CA group consistently had scores that fell in between the ADHD and CNA groups, suggesting that this group is having more difficulty than the CNA group but not as much difficulty as the ADHD group (see Table 2).

*Exploratory Correlations*

Given that the effect size calculations suggest that the CA group may differ from the CNA group on a number of the cognitive measures, correlations were conducted to specifically determine the strength of the relationship between ADHD symptomatology and cognitive functioning, within the creative sample. Since the CA group mostly displayed symptoms of inattention, parent's ratings on the Inattentive subscale of CRS-R were used. Strong negative correlations were found between inattention and WISC III Processing Speed ($r$ = -0.364, $p < 0.05$) and Coding ($r$ = -0.363, $p < 0.05$); T-scores for Stroop Word ($r$ = -0.302, $p < 0.05$), Colour ($r$ = -0.441, $p < 0.05$), and Colour-Word ($r$ = -0.382, $p < 0.05$); STOP percent correct ($r$ = -0.425, $p < 0.05$), and go reaction time ($r$ = -0.387, $p < 0.05$). There was a strong positive correlation between inattention and RAN numbers ($r$ = 0.356, $p < 0.05$), letters ($r$ = 0.297, $p < 0.05$), colours (r = 0.373, $p < 0.05$), and objects ($r$ = 0.311, $p < 0.05$) and stop-signal-go reaction time (r = 0.488, $p < 0.01$). No relationship was found between inattention and WISC III Freedom from Distractibility, Arithmetic, Digit Span, Symbol Search, STOP standard deviation of go-reaction-time, TOL points for correct solutions, TOL time to make first move and number of ideas on Maier's two string problem. Overall, these results show that slower reaction times are closely related to the inattention symptom of ADHD in this creative group; and that creative children perform equally as well on most IQ and executive functioning measures, regardless of severity of ADHD symptomatology.

Discussion

Results of this study showed that, in accordance with Cramond's (1994a) findings, a high percentage (40%) of creative children displayed significant levels of ADHD symptomatology that were within a clinical range on standardized scales of ADHD. This percentage is significantly higher than one would expect in the normal population. Given the cutoff used to identify children with ADHD symptomatology was 1.5 SD above the mean, one would expect approximately 9% of children within the general population to display clinically elevated levels of ADHD symptomatology. That this current study found a rate over four times expected suggests that ADHD symptomatology in a creative population is a relatively common occurrence.

This study went on to establish, via a standardised interview, that the creative children with elevated Conners scores did not meet full criteria for ADHD. For the most part, although parents endorsed symptoms of ADHD, they generally did not believe that their children were significantly impaired by them. Further, the teacher ratings were within normal limits, suggesting that these children were not experiencing any difficulties at school that were of concern to teachers. High levels of inattention in creative children are not surprising given the number of past researchers and theorists arguing that inattention is a necessary feature of creativity (e.g., Carson et. al., 2003; Eysenck, 1999, Simonton, 2003) and Carson et. al.'s (2003) work on latent inhibition and creativity. This study implicates that while ADHD symptoms are common in the creative population, a full diagnosis of ADHD is not.

This study is the first to then take these two types of creative children (with and without ADHD symptoms) and compare them on neurocognitive functioning with ADHD children with normal creativity. On measures of Full Scale IQ, working memory and executive functioning, the creative group with ADHD symptoms performed significantly better than the ADHD group and very similarly to the creative group without ADHD symptoms. Alternatively, on measures of processing speed, reaction time and naming speed, the creative group with ADHD symptoms consistently performed in between the ADHD and creative group without ADHD symptoms, suggesting that this group of children is somewhat impaired on these cognitive processes. Consistent with these results, correlational analyses confirmed that as creative children's inattention increased, their reaction times decreased and their naming speeds increased. However, the presence of inattention did not appear to be related to deficits in overall IQ measures or executive functioning, suggesting that inattentive creative children process information slower and react slower to stimuli but these deficits do not appear to impair more general cognitive abilities.

As 40% of the creative children recruited for the study displayed symptoms of ADHD, one needs to ask why it is that so many creative children display significant levels of ADHD symptomatology? This question remains unanswered in the literature to date, but a possible explanation may come from Carson et. al.'s (2003) work on latent inhibition and creativity. These authors found that actual lifetime creative achievers had significantly more difficulty filtering out possibly irrelevant information than controls, and suggested that this deficit, in combination with high IQ, was actually aiding their creativity. Therefore, it may be that the neurocognitive deficits found in the creative children with ADHD symptoms occur due to the fact that their inability to filter stimuli is slowing them down. What possibly distinguishes the creative children from ADHD children is that due to their high IQ, they are able to process the vast array of information that they receive and incorporate it into their ideas; whereas ADHD children may not be able to effectively process and incorporate the information they receive.

One difficulty with Carson et al's (2003) theory is that they suggest that high IQ is a necessary component for creativity and although it has been posited by the threshold theory that creativity and IQ are correlated up until an IQ of 120 (e.g. Albert & Elliot, 1973; Barron, 1969), empirical investigations of this theory have resulted in contradictory and inconclusive results. It appears that results differ depending on the measures of both creativity and IQ/achievement that are used (Runco & Albert, 1986). For example, a study by Marcelino (2001) showed that IQ (as measured by the WISC) and Torrance Test of Creativity scores were not significantly correlated; where as Guilford and Christensen (1973) used Lorge-Thorndike IQ scores and five divergent thinking tests and found that "the higher the IQ, the more likely we are to find at least some individuals with high creative potential" (p. 251). Further, it has been stated in the literature that one can be creative without having high IQ, and be highly intelligent without being creative (Sternberg, 1999). Thus, it is important to differentiate creativity from IQ and investigate it as a separate domain. Indeed, a number of the children (17%) in this study had an estimated IQ in the average range (i.e. less than 1SD above the mean) and yet showed high creativity scores, highlighting that while they are highly correlated constructs, high IQ is not a necessary condition for high creativity.

A further question in relation to creativity is that, if deficits in latent inhibition are linked to creativity, then why it is that only 40% of the children in the creative group displayed these "ADHD-like" behaviors? It may be due to the fact that the Torrance Tests of Creative Thinking is a measure of creative *potential* rather than a measure of *actual* creative achievement. It is possible that those children with high IQ and creative potential, who are also open to more stimuli due to their latent inhibition deficits, will be the ones who will become true creators.

Furthermore, it may be the use of participants who score highly on measures of creative potential rather than ones who are actual creators, which has lead to the confusion and contrary results in the literature on cognitive functioning and creativity to date. Future research in this area should focus more on populations of actual life time achievers.

The finding that both ADHD and creative children with symptoms of ADHD had difficulties in naming speed and reaction times, supports Barkley's (1997) theory that deficient cognitive functioning is, at least in part, related to the behavioral manifestations of ADHD. Furthermore, when comparing the ADHD and creative group with ADHD symptoms, it appears that as cognitive functioning deficits increase so does the severity of the ADHD symptomatology (as reported on the CPRS-R). This study is the first to document the presence of these difficulties in a creative sample.

However, our results suggest that it may not be poor executive functioning in general (such as working memory, planning, and problem solving) that is the driving mechanism behind the behaviors seen in ADHD, but rather processing speed and reaction times in particular. The ADHD group was no different from controls on a number of executive functioning measures including working memory (Digit Span, Symbol Search), inhibition (Stroop Interference, Stroop negative priming), planning and problem solving (TOL, and Maier's two-string problem), yet on measures of reaction time and naming speed (Processing Speed; RAN numbers, letters, colours, and objects; Stroop word and colour; Stroop negative priming; stop-signal-go reaction time; TOH time to make first move), the ADHD group were found to be significantly more impaired than controls. These findings add to the growing literature linking colour naming deficits, overall slow reaction times and processing speed deficits with ADHD (e.g., Nigg, Hinshaw, Carte & Treuting, 1998; Rucklidge & Tannock, 2002). These findings also replicate past studies which found no differences between ADHD and controls on Stroop interference (e.g., Nigg, Blaskey, Huang-Pollock & Rappley, 2002), and TOL in ADHD predominantly inattentive type (Klorman, et. al, 1999; Nigg et. al., 2002).

*Limitations*

There are a number of limitations that hinder the generalizability of these results. First, because the creative groups were formed experimentally and not directly recruited for ADHD symptomatology, the sample sizes of both of the creative groups were small, impacting on power. Second, we did not assess the ADHD group with a standardised interview; instead the diagnosis came from community practitioners and was then confirmed with rating scales, which inevitably produces some variability into the diagnostic procedures. As such, inter-diagnostician reliability could not be assessed. Third, the ADHD sample consisted of all three subtypes types of ADHD (i.e. predominantly inattentive, predominantly hyperactive and combined type), yet the sample size was too small to allow analyses between subtypes. Fourth, while it is hard to know what influence IQ had on the results, an attempt to control for IQ did not have a significant effect on the pattern of results. Fifth, only one measure of creativity was used to ascertain whether or not children where highly creative. Finally, the groups had unequal numbers of male and female participants with too few girls in the ADHD and creative group with ADHD symptoms to determine whether there were differences in functioning based on gender.

*Clinical Implications*

There is a concern in the literature that creative children will be misdiagnosed with ADHD. This study does not support this concern. Indeed, despite the fact that a large percentage of the children recruited for high creative ability showed significant elevations on ratings of ADHD symptoms, *none* of them met full criteria for a diagnosis of ADHD, showing that these symptoms are not proving to be problematic in their environments, and are not raising concerns for parents or teachers. Further, none of them entered the study with a diagnosis of ADHD suggesting that the symptoms were not significant enough to warrant referral. Thus, concerns of misdiagnosis appear unwarranted. The assumption behind the concern about misdiagnosis appears to be that the underlying mechanisms leading to these behaviors are different and thus creative children would not benefit from the standard treatment offered to children with ADHD (Cramond, 1994b). The results of this study suggest that the underlying mechanisms may indeed be the same and that these creative children do have difficulties on some of the same tasks as ADHD children, although they appear less severe. Therefore, one cannot conclude that these children would not benefit from similar treatment approaches. Instead, it may be that the creative children displaying ADHD symptoms have a vulnerability that, to date, has not been stressed. Further, it may be that these children's environment is more suited to their needs and enables them to benefit from their inattention and develop their creativity. Only further investigations of treatment approaches for creative children impaired by ADHD symptoms would clarify the best practice parameters for these children.

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Table 1

*Sample characteristics: means and standard deviations*

| | *ADHD (n=29)* | | *CA (n=12)* | | *CNA (n=18)* | | *NC (n=30)* | | Wilk's Lambda | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | Mean | SD | Mean | SD | F(3,88) | Contrasts[a] |
| Age | 11.44 | 0.85 | 11.10 | 0.94 | 11.10 | 0.80 | 11.10 | 0.89 | 1.018 | |
| SES | 48.64 | 12.99 | 66.33 | 15.20 | 70.58 | 8.58 | 61.25 | 9.95 | 13.017*** | ADHD<CA,CNA,NC |
| *WISC III Scaled Scores (SS)* | | | | | | | | | | |
| Estimated FSIQ | 106.03 | 15.53 | 127.50 | 13.60 | 127.78 | 11.91 | 117.10 | 13.53 | 11.843*** | ADHD<NC<CA,CNA |
| TTCT (Percentiles) | 37.83 | 30.48 | 94.58 | 3.23 | 94.89 | 3.85 | 45.97 | 23.37 | 39.036*** | ADHD,NC<CA,CNA |
| *CPRS-R (T-scores)* | | | | | | | | | | |
| Inattentive | 75.43 | 8.53 | 70.75 | 3.41 | 47.18 | 5.46 | 47.32 | 5.56 | 116.679*** | ADHD,CA>CNA,NC |
| Hyperactive | 82.07 | 8.29 | 63.75 | 8.64 | 48.29 | 6.07 | 47.80 | 4.93 | 132.114*** | ADHD>CA>CNA,NC |
| DSM-IV total | 81.07 | 6.19 | 67.58 | 2.81 | 47.47 | 5.68 | 47.32 | 4.97 | 227.483*** | ADHD>CA>CNA,NC |
| *CTRS-R (T-scores)* | | | | | | | | | | |
| Inattentive | 57.10 | 10.18 | 53.08 | 10.00 | 45.28 | 3.14 | 45.23 | 3.89 | 12.910*** | ADHD,CA>CNA,NC |
| Hyperactive | 57.25 | 13.56 | 48.00 | 5.01 | 46.33 | 5.12 | 44.27 | 3.78 | 10.007*** | ADHD>CA,CNA,NC |
| DSM-IV total | 57.95 | 12.46 | 51.00 | 7.65 | 45.17 | 3.99 | 44.32 | 3.11 | 13.286*** | ADHD>CNA,NC |

*Note:* [a]Tukey's HSD, $p < .05$, CA = creative with ADHD symptomatology, CNA = creative without ADHD symptomatology, NC = normal control, CPRS-R = Conners' Parent Rating Scale-Revised, CTRS-R = Conners' Teacher Rating Scale-Revised, TTCT = Torrance Tests of Creative Thinking, *** $p < 0.001$.

Table 2

*Neurocognitive functioning by group: means and standard deviations*

| | *ADHD (n=29)* | | *CA (n =12)* | | *CNA (n=18)* | | *NC (n=30)* | | Wilk's Lambda | | Effect Sizes *(d)* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | ADHD | CA& |
| Variable | Mean | SD | Mean | SD | Mean | SD | Mean | SD | F(3,88) | Contrasts[a] | &CA | CNA |
| **Working Memory** | | | | | | | | | | | | |
| *WISC III (SS)* | | | | | | | | | | | | |
| Digit Span | 8.59 | 2.47 | 11.42 | 4.12 | 11.94 | 2.10 | 9.87 | 2.47 | 6.967*** | ADHD<CA, CNA | 0.83 | 0.16 |
| | | | | | | | | | | NC<CNA | | |
| Raw Digits Forward | 8.28 | 1.53 | 9.17 | 2.04 | 9.56 | 1.50 | 8.47 | 1.59 | 2.868* | ADHD<CNA | 0.49 | 0.22 |
| Raw Digits Backward | 4.38 | 1.50 | 5.75 | 2.26 | 6.11 | 1.57 | 5.30 | 1.75 | 4.361** | ADHD<CNA | 0.71 | 0.19 |
| Arithmetic | 8.66 | 3.29 | 13.67 | 2.64 | 13.28 | 4.03 | 11.40 | 3.32 | 9.882*** | ADHD<CA, CNA, NC | 1.68 | 0.11 |
| Freedom from Distractibility | 92.69 | 14.21 | 113.33 | 14.78 | 116.67 | 14.91 | 104.57 | 13.38 | 12.715*** | ADHD<CA, CNA, NC | 1.42 | 0.22 |
| | | | | | | | | | | NC<CNA | | |
| **Processing and Naming Speed** | | | | | | | | | | | | |
| *WISC III (SS)* | | | | | | | | | | | | |
| Coding | 8.92 | 2.96 | 10.92 | 2.47 | 13.56 | 2.41 | 12.07 | 2.89 | 13.043*** | ADHD<CNA, NC | 0.73 | 1.08 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | CA<CNA | | |
| Symbol Search | 10.17 | 1.50 | 12.75 | 2.45 | 13.67 | 3.24 | 12.30 | 2.73 | 5.781** | ADHD<CNA | 1.27 | 0.32 |
| Processing Speed | 98.21 | 14.78 | 110.67 | 10.55 | 119.67 | 12.19 | 112.20 | 13.01 | 11.056*** | ADHD<CA, CNA, NC | 0.97 | 0.79 |
| *RAN (sec)* | | | | | | | | | | | | |
| Numbers | 27.58 | 8.61 | 25.26 | 6.05 | 20.54 | 3.50 | 23.42 | 5.32 | 4.878** | ADHD>CNA | 0.31 | 0.96 |
| Letters | 26.97 | 7.71 | 24.60 | 4.71 | 21.00 | 4.83 | 22.89 | 4.09 | 4.733** | ADHD>CNA,NC | 0.37 | 0.75 |
| Colours | 46.54 | 12.51 | 41.63 | 8.23 | 34.17 | 7.78 | 38.03 | 7.80 | 7.212*** | ADHD>CNA,NC | 0.46 | 0.93 |
| Objects | 45.27 | 8.41 | 45.43 | 9.04 | 38.87 | 6.77 | 39.50 | 6.41 | 4.922** | ADHD>CNA,NC | 0.01 | 0.82 |
| **Reaction Time and Inhibitory Control** | | | | | | | | | | | | |
| *Stroop Task (T-scores)* | | | | | | | | | | | | |
| Word | 42.65 | 7.37 | 46.75 | 5.66 | 52.11 | 5.80 | 50.17 | 6.51 | 9.886*** | ADHD<CNA,NC | 0.62 | 0.94 |
| Colour | 40.93 | 8.21 | 44.00 | 6.47 | 51.89 | 8.72 | 48.77 | 8.04 | 8.443*** | ADHD<CNA,NC | 0.42 | 1.03 |
| | | | | | | | | | | CA<CNA | | |
| Colour-Word | 47.48 | 11.48 | 51.00 | 10.29 | 59.50 | 8.07 | 56.57 | 7.64 | 7.609*** | ADHD<CNA,NC | 0.32 | 0.92 |
| Interference | 54.41 | 8.26 | 56.92 | 4.78 | 57.17 | 4.29 | 56.67 | 5.40 | 1.028 | | 0.37 | 0.06 |
| *Stop Task* | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Go reaction time (msec) | 706.75 | 185.78 | 634.13 | 127.42 | 698.58 | 65.30 | 704.80 | 134.42 | 0.839 | | 0.46 | 0.64 |
| SD go reaction time | 264.64 | 123.54 | 193.08 | 47.70 | 177.94 | 42.89 | 191.76 | 52.36 | 5.926*** | ADHD>CA,CNA,NC | 0.76 | 0.33 |
| Stop-signal-go reaction time (msec) | 347.25 | 211.00 | 263.15 | 87.42 | 190.72 | 47.76 | 226.50 | 93.39 | 5.934*** | ADHD>CNA,NC | 0.52 | 1.03 |
| Percent correct | 95.29 | 4.42 | 96.74 | 2.82 | 98.61 | 1.84 | 97.80 | 2.29 | 5.068** | ADHD<CNA,NC | 0.39 | 0.79 |
| **Executive Functioning** | | | | | | | | | | | | |
| *TOL* | | | | | | | | | | | | |
| Points for solutions | 21.21 | 7.03 | 27.50 | 5.16 | 26.56 | 6.94 | 24.13 | 6.59 | 3.696* | ADHD<CA,CNA | 1.02 | 0.14 |
| Time to make first move (sec) | 1.72 | 1.74 | 3.94 | 2.44 | 6.11 | 4.77 | 5.82 | 6.34 | 5.351** | ADHD>CNA,NC | 1.05 | 0.57 |
| *Maier's two string problem (# ideas)* | 4.79 | 2.16 | 6.58 | 1.88 | 7.89 | 3.45 | 4.9 | 1.15 | 9.578*** | ADHD<CA,CNA | 0.88 | 0.47 |
| | | | | | | | | | | NC<CNA | | |

*Note:* [a]Tukey's HSD, $p<0.05$, CA = creative with ADHD symptomatology, CNA = creative without ADHD symptomatology, NC = normal control, TOL = Tower of London, $^{**}p < .01$, $^{***}p < .001$