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Reliability and validity of parent/teacher rating of hyperactivity in children with AD/HD using actigraphic measurements as an objective method

Yannick Massicotte

McGill University, Montreal

August 2000

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements of the degree of Masters of Science.

Abstract

Parent and teacher ratings of hyperactivity are compared with an objective measure of activity level (actigraphy) for 19 ADHD children and 18 control subjects. All subjects wore the actigraph during a full day diagnostic assessment. Mean actigraph scores were calculated for the structured (including time during the Continuous Performance Test (CPT)) and unstructured element of the assessment. The structured, unstructured and CPT settings were significantly differentiated for the sample as whole by actigraphic measures. However no significant difference in activity level was found when we compared the subgroups (Controls, medicated ADHD, non-medicated ADHD). Parent ratings were not correlated with actigraphic measures in any setting. Teacher ratings on the Hyperactivity Index were significantly correlated with activity during the structured and unstructured setting for the whole sample and the ADHD subjects. These data indicate that teacher ratings of hyperactivity are more reliable than parent ratings on identical items when one is interested in gross motor activity. Issues concerning the situational relevance of rating scales and applications of actigraphic technology are discussed.

Abrégé

Les percéptions des parents et professeurs en ce qui regarde l'hyperactivité sont comparées avec une mesure objective d'activité (Actigraphie) pour 19 enfants avec ADHD et 18 contrôles. Tous les sujets ont porté l'actigraph pendant une journée complète de cotisation clinique. L'activité moyenne a été calculée pour les périodes structurées (incluant durant l'administration du Continuous Perfomance Test (CPT)) et non-structurés. L'activité moyenne durant ces periodes fut différenciée par l'actigraph, mais aucune différences significative a pu être trouvée lorsque les différents sous groupes ont été comparés (contrôles, ADHD médicamentés et les ADHD non-médicamentés). Aucune corrélation n'a été trouvée entre la percéption d'hyperactivité des parent et la mesure actigraphique. Toutefois, les résultats démontrent une corrélation significative entre la pérception d'hyperactivité des professeur et les sujets ADHD pendant les périodes structurés et non structurés. Les résultats indiquent que la percéption des professeur sonts plus fiables quand l'intérêst est l'activité motrice. La pertinence des échelles d'evaluation et les applications futures de l'actigraph sont discutées.

Acknowledgement

I gratefully acknowledge the dedication of my supervisor Dr. Lily Hechtman. Without her devotion to research and faith in me, this thesis would not have been possible. Special thanks to Joy Etcovitch, Angie Lambrinos and Rosie Bourdeau for their encouragement and technical assistance. I would like to express my appreciation to my parents who have supported me in all my endeavours and continue to do so. Mumbi, Phryday, Musko and Gaston are especially appreciated for being themselves and providing essential stress relief.

Finally, I would like to thank my loving wife, Enid Stiles, for her support and understanding.

Introduction

General Introduction to ADHD

Attention-deficit hyperactive disorder (ADHD) is among the most frequently diagnosed child psychiatric disorder and is estimated to affect 3-5 % of school aged children in North America (Barkley, 1996). The three primary symptoms observed in ADHD are inattention, impulsivity and hyperactivity. These behavioural deficits arise relatively early in childhood and usually persist in varying degrees to adulthood (Weiss & Hechtman, 1993). Treatment involves support and education of parents, appropriate school placement and pharmacotherapy. The primary medications are psychostimulants, namely Ritalin (methylphenidate). To date, there is only evidence of short-term benefit from stimulant medication providing symptomatic relief while the child is medicated (Greenhill, 1992). Comorbidity is present in as many as two thirds of clinically referred children with ADHD, including up to 50% for oppositional defiant disorder (ODD), 30% for conduct disorder (CD), 15% to 20% for mood disorders, and 20% to 25% for anxiety disorders (Biederman, 1991; Murphy & Barkley, 1996). Despite a decline in their levels of hyperactivity, and an improvement in their attention span and impulse control, 70 to 80% of ADHD children are likely to continue to display these symptoms into adolescence to an extent inappropriate for their age group (Hechtman, 1999). These impairments often result in poor scholastic achievement. Since advanced levels of reading, writing and

mathematical skills are now a common requirement in the workplace, ADHD has received increasing attention from both parents and educators. While most research on ADHD has focused on children and adolescents, in recent years considerable attention has been drawn to adult ADHD. Longitudinal studies have shown that over 50% of adults diagnosed Hyperactive as children continue to experience significant problems with concentration, impulsivity, and social interaction. These symptoms often result in difficulties with work, interpersonal relationships, and self-esteem (Weiss & Hechtman, 1993). Thus, thorough assessment of problem behaviours and appropriate intervention are key in the management of ADHD and improving long-term outcome.

Clinical Diagnosis of ADHD

Presently there are no formal tests to establish the diagnosis of ADHD. There are no specific physical or neurological findings that are pathognomonic of ADHD. Information gathered from parent and/or teacher reports and ratings scales along with observations of the child in a consultation room are the usual ways in which the diagnosis of ADHD is attained. The symptoms associated with ADHD are often difficult to observe during a professional office visit. Patients are often seen for only 10 to 15 minutes (Silver, 1992). Thus the clinician must rely heavily on reports and rating scales and use his/her clinical judgement when determining the diagnosis and appropriate intervention. Generally the rating scales used in assessments are based on

normative data derived from large samples (Conners, 1990). These scales permit the clinician to determine the degree of deviance displayed by a particular child within the population of same age and same sex children. One such instrument, the Conners' Parent and Teacher Rating Scales originally designed to help identify hyperactive children are now used in characterising a number of other symptoms and behavioural problems (Conners & Sitarenios, 1998a, 1998b). Despite the fact that rating scales have considerable ecological validity for assessing ADHD, they are of limited value for assessing the specificity of individual symptoms associated with this disorder. Many scale developers have employed various types of factor analyses to create subscales, which are then labeled as reflecting certain constructs or dimensions of child behaviour (e.g., Aggression, Hyperactivity, etc.) (Barkley, 1996; Conners, 1990). However, these constructs are often composed of behaviours that are correlated and/or associated with each other. Therefore these subscales identify different patterns of behaviour as opposed to specific symptoms.

Assessing Hyperactivity

Hyperactivity, a central feature of ADHD, is often defined as excessive or developmentally inappropriate levels of motor activity. Restlessness, fidgetiness, squirming in one's seat and often the appearance of being always "on the go" or as if "driven by a motor" are commonplace (American Psychiatric Association, 1994). These movements are often irrelevant to the task or situation and at times seem

purposeless. Although considered a fundamental trait and relevant to both normal and abnormal behaviour, hyperactivity has proved more complex to define than previously thought (Chess &Thomas, 1978; Taylor, 1998). Hyperactive behaviour may be organised and controlled, but in the child with ADHD, impulsivity or lack of self-regulation often accompanies motoric overactivity. This latter combination is the type of "overactivity" that is considered deviant for ADHD children. The hyperactivity dimension of ADHD has also been shown to fluctuate in its severity across settings and caregivers (Barkley, 1996). In free play or low demand settings, ADHD children are less distinguishable from normal children than in highly restrictive settings.

As psychiatric diagnoses have evolved over the years, increasing attention has been given to altered activity levels as an important diagnostic criterion in many conditions. In the DSM-I and DSM-II, seven disorders required clinicians to assess motor activity. In the DSM-III this had increased to 16 disorders and the current version DSM- IV, recognises over 29 disorders that require the assessment of altered activity level (Tryon, 1986; American Psychiatric Association, 1994). Despite the recognition of altered motor activity in disorders such as anorexia nervosa, conduct disorders and depression, the exact nature or pattern of the activity is rarely known or even investigated (Teicher, 1995). As a consequence, there is no clear-cut objective data on how to define the levels and pattern of normal and hyperactive behaviour (Cammann & Miehlke, 1989). Such detailed information may prove to be useful in

differentiating between types of altered activity thus enhancing the knowledge of current disorders associated with altered activity levels. To date, the most common instruments for assessing hyperactivity are the rating scales and observational reports.

Rating Scales

Behavioural rating scales offer tremendous benefits to the clinical evaluation and management of children with ADHD. They are easy to administer, inexpensive and most are based on strong empirical data (Barkley, 1996). There are however problems inherent in the use and interpretation of these scales. One of the main drawbacks lies in their subjective nature, which can often result in low agreement among different informants. This is evident in both clinical practice and research data. In a meta-analysis of 119 studies, Achenbach et al. (1987) found considerable consistency between reports by pairs of parents, teachers and mental health workers, but the correlation among different types of informants was found to be as low as 0.28 (Ho, 1996). A recent study investigating the parent-teacher concordance for DSM-IV subtypes found that agreement between parents and teachers on structured diagnostic interview regarding the categorical diagnosis of ADHD and its subtypes are relatively poor with virtually no agreement regarding ADHD subtype (Mitsis, 2000). These differences may be the result of a number of factors. Parents and teachers observe children in different settings. In the classroom, the child is generally more susceptible to problems with hyperactivity, distractibility, and attention. The

discrepancy between parent and teacher reports may thus be due to real differences in the situations where the child is observed. Clinical judgement assessing the quality of the two data sources is often the last resort. These clinical ratings may also be susceptible to halo effects in which other behavioural disturbances (e.g., defiant behaviours) inflate perceptions of ADHD symptoms (Weinberg, 1991). This point is especially salient when considering co-morbid disorders associated with ADHD. Studies have shown that over half of children with ADHD are also at risk for comorbid oppositional-defiant, conduct, mood, anxiety, and learning disorders (Biederman, 1991; Hechtman, 1999). Even though rating scales provide an ecologically valid profile of child impairment, Achenbach (1995) has suggested that the use of clinical ratings in the absence of laboratory-based indicators may result in spurious rates of co-morbidity. Another issue lies in the interpretation of the results from these scales. While inattention, impulsivity and hyperactivity appear conceptually distinct, it may be difficult to distinguish the contribution of each through behavioural observation alone (Halperin, 1992). For example a child leaving his/her seat during class may be difficult to characterise as impulsive, inattentive or hyperactive on teacher ratings. Despite these important shortcomings, clinicians continue to depend to some degree on subjective behavioural ratings of parents and teachers in making a diagnosis of ADHD.

Objective Measures

As the need to quantify and characterise the contribution of the different symptoms becomes increasingly important, the tools used in obtaining a diagnosis must provide accurate and diagnostic relevant information. The hyperactivity dimension of ADHD constitutes a separate component from impulsivity and inattention and can be objectively analysed by various methods. Direct observation has proved to be fairly accurate in its perception of activity. However cost and time involvement in direct observation has lead researchers to investigate mechanical devices to measure activity. Instrumented objective methods of measuring activity have the advantage and limitation of being both independent and unidimensional (Pinto & Tryon, 1996; Tryon, 1993). These tools focus exclusively on activity level and respond only to physical forces. The use of objective measurements allows the investigator the added advantage of further defining the hyperactivity in terms of quantity and pattern rather than simply categorically. Furthermore, quantitative assessment of activity also provides a wealth of data about activity at specific times. While most objective measures provide meaningful information regarding activity level, they are of limited value as diagnostic tools by themselves. These tools do not provide any information regarding the level of co-ordination of movements, the purposefulness, appropriateness or the goal directedness of the activity they record. Activity data collected from some devices may also be difficult to interpret due to the lack of studies validating their use. Despite these shortcomings, researchers and

clinician have increasingly acknowledged the advantage of using objective measures as an adjunct to conventional diagnostic tools that rely on the subjective experience of the patient or information from sources associated with the individual.

For more than 20 years, many experiments have been carried out using instruments to measure motor activity. Among the devices used were accelerometers, electrical devices with wire leads from a main electrical unit attached to the ankle or wrist (Pope, 1979; Miller, 1994). Ultrasound transistorised devices detecting motion and photoelectric cell movement-detectors recording interruptions of light beams aimed at the floor of the observation room were both used in research in the late 1970's (Johnson, 1977; Milich, 1982). Also used were digital electronic step counters, devices attached around the waist and sensitive to vertical movement (Saris, 1977). These devices all provide some form of objective measurements of activity. However, they all have a common drawback in that they may only be used in controlled laboratory environments raising issues of ecological validity. More recently advances in microprocessor technology and miniaturisation have resulted in the development of a number of reliable and affordable devices that can provide detailed information on activity in the ambulatory individual.

The Actigraph

The actigraph, a device slightly larger than a man's wristwatch measures activity by recording movements with accelerations of <0.03g. The actigraph can

count and store the number of times accelerations change above a certain threshold per unit time (User's guide for ACT, 1991). Research using the actigraph has grown over the last few years mainly because of its desirable properties: objectivity, validity, portability, reliability, stability, privacy, and cost effectiveness (Teicher, 1995; Tryon, 1991; Saris, 1977). The nature of the actigraph allows it to be worn with minimal discomfort for days. This permits the investigator to assess the activity level in many situations across continuous time frames.

Actigraphy has recently found widespread use in studies involving sleep. Recent studies have shown increased instability in sleep onset, sleep duration, and true sleep in the ADHD subjects compared to a control group. Discriminant analysis also revealed that childrens' classification (ADHD versus control) could be significantly predicted on the basis of their sleep measures (Acebo et al., 2000; Dagan et al., 2000; Gruber et al., 2000). The actigraph has the ability to detect wake and sleep states and can provide estimates of sleep latency, number of awakenings, and overall sleep efficiency (Sadeh et al., 1991). These findings have enabled researchers to use this technology in the assessment of circadian patterns in human activity (Lieberman et al., 1989; Brown et al., 1990). The actigraph is not intended to be used as an independent diagnostic tool. It can however be utilised as an efficient complement to existing diagnostic tools. As mentioned earlier, there is often a discrepancy in the perception of hyperactivity as scored on the Conners rating scales between different informants (Achenbach et al., 1987; Mitsis, 2000). In this instance,

using the actigraph would provide an activity profile of the child across all settings giving the clinician/researcher a more complete picture of the pervasiveness of the hyperactivity. These data may be useful to see if there is a change in activity level when the child is off medication (e.g. summer holiday). Information derived from actigraphy may also be useful in monitoring the effects of interventions in the titration of medication dosages and determining drug effects.

By way of analogy, the clinician detecting a cardiac arrhythmia in a patient by palpating their pulse would prompt further observation with a cardiogram or rhythm strip. In a similar manner, actigraphy provides a tool that can enable researchers and clinicians to detect disturbances in activity that are often missed in the office (Teicher, 1995).

The actigraph has also proven itself an effective tool in ADHD research (Borcherding et al., 1989; Yaron, 1987; Porrino et al., 1983a, 1983b; Stevens, 1978). Researchersusing the actigraph in conjunction with other instruments in assessing ADHD, have reported an increase in the specificity and sensitivity of the diagnosis. Inoue et al. (1998) conclude that using actigraph scores combined with continuous performance task (CPT), results in a more accurate diagnosis of ADHD than the CPT alone. Porrino et al. (1983a) collected actigraphic data continuously for 10 days from 12 boys referred for hyperactivity. Porrino demonstrated that the hyperactivity displayed in ADHD is one that is pervasive across situations (diaries and school schedules were used to determine activity levels for specific settings) (Porrino et al.,

1983a). Furthermore, activity scores for ADHD children were significantly greater in every situation when compared to a control group. While the differences in activity level during unstructured play disappeared somewhat, marked differences in activity were observed during periods of structured school time. This study demonstrated that motor excess does not occur exclusively under highly structured situations but is more generalised to all times including during sleep and weekends (Porrino et al., 1983a). In a subsequent study by Porrino et al. (1983b), using 12 boys, the use of methylphenidate was shown to normalise the activity level of ADHD to levels seen in control subjects. It was also shown that stimulant medication decreased activity for 8 hours followed by a slight increase in activity as the medication wore off. This was the first objective demonstration of the "rebound side effect" (Porrino et al., 1983b). More recently actigraphy was used to compare subtypes of ADHD in a clinical settings. In this study no difference was found in the activity levels of the children with ADHD predominately inattentive type with the ADHD combined type. This finding contradicts specifications in the DSM-IV that suggests that children with ADHD combined type should be more hyperactive than children with ADHD inattentive type (Dane, 2000). Clearly actigraphy has played an important role in testing predictions made by the current model of ADHD. Findings from objective laboratory based measures will also be increasingly important in defining our current understanding of ADHD.

Limitations of Actigraphic Measures

While the ecological validity of instrumented activity measures have raised some concerns (Barkley, 1991), the actigraph has been shown to be an effective and reliable tool when the researcher is interested in activity. The actigraph is not intended to be used as a diagnostic tool, but its use as a complementary source of information is logical. One of the limitations of the actigraph is that the measurement of activity counts, does not allow the discrimination of task-related and non-task-related movements. The actigraph records all movements but does provide information regarding the appropriateness or usefulness of the activity. With the use of a daily log however certain assumptions can be made about the expected level of task-related movements. In the present study, actigraphic data was recorded while the children were involved in specific tests. During the Continuous Performance Test for example the subjects were asked to press the spacebar on a keyboard when they saw a certain letter appear on the screen. During this test the subjects were seated facing a computer screen. It was assumed that the only task-oriented movements would be pressing the spacebar. In other settings, the use of diaries and schedules are essential when the researcher wishes to compare activity levels between subjects. Although type of movement cannot be discerned by actigraphic recordings alone, information regarding frequency and intensity provided by the actigraph may in itself be indicative of some types of impairment.

Purpose of Study

The purpose of the present study is to determine the relative validity of the parent and teacher perception of the child's activity when compared to actigraphic data. By continuously recording activity across different settings, activity measurements were determined during different tasks during a clinical evaluation. Parent's rating were expected to correlate with activity recorded during unstructured time frames and teacher ratings to correlate with activity measurements recorded during structured tasks such as the CPT. This would parallel the environments in which informants see the subjects and on which the ratings are based. Teachers observe children mainly during structured settings such as classrooms whereas parents observe children at home where the settings are generally less structured. The degree of structure and its related response in activity from both ADHD and controls may provide some information with respect to the issue of situational hyperactivity. It has also been postulated that the greater the demand on attention and concentration, the more impairing the symptoms of hyperactivity become in the ADHD child (Barkley, 1996; Cammann & Miehlke, 1989). If this phenomenon does occur, the greatest differences in activity level between ADHD and controls are expected during structured settings when attentional demands are the greatest. During unstructured settings (lunchtime, recess) differences in activity levels between the groups are expected to be less significant.

Methods

Participants

The sample as a whole consisted of 37 subjects ranging in age from 10 to 13 years. Participants included 19 ADHD subjects (16 boys, 3 girls) mean age = 11.57, SD = 0.19, and 18 Local Normative Comparison Group (LNCG) subjects (14 boys, 4 girls) mean age = 11.27 SD = .21. The ADHD group comprised of 16 Caucasians and 3 racially mixed subjects, while the LNCG consisted of 17 Caucasians and 1 Asian subject. The ADHD subjects were children participating in a 36 month follow-up assessment as part of the NIMH Multimodal Treatment Study of Children with Attention Deficit Hyperactive Disorder (ADHD), the MTA study (Arnold et al., 1997). In 1997, the ADHD subjects began the study aged 7-9 years with a diagnosis of ADHD, all met the criteria for the combined subgroup as defined in the DSM-IV (American Psychiatric Association, 1994). The Local Normative Comparison Group (LNCG) consisted of children matched for age and gender. These children were recruited in 1998 from the same schools as the ADHD sample and served as the comparison group in the follow-up MTA study.

Measures

Assessments were scheduled to begin in the morning and consisted of two testing periods (AM and PM) separated by a lunch period lasting generally one hour.

Mean duration of the total assessment was 4h 45min with a range of 3h 18min to 6h 30min. During the morning and afternoon sessions, a number of psychometric tests and research measures were administered to the parent and the child. Some of these measures included theWeschler Intelligence Scale for Children (WISC-III) and the Diagnostic Interview Schedule for Children (DISC-C) (Wechsler, 1991; Scaffer et al., 2000). The child was also asked to participate in the Conners' Continuous Performance Test (CPT) (Conners, 1994; Lahey et al., 1994). During the testing sessions, the parent was asked to fill out various questionnaires and rating scales. The parent and child were given an hour break during which time they left the premises for lunch. Most assessments proceeded in this fashion ending typically sometime between 3 and 4 PM. For four LNCG subjects, assessments were scheduled in the afternoon and these participants did not benefit from an extended break. As a result, no actigraphic data is available for these subjects in an unstructured setting. The assessment protocol however remained qualitatively identical to the rest of the sample.

Parent/teacher Questionnaires

The Conners' Parent Rating Scale (CPRS-93) and the Conners' Teacher Rating Scale (CTRS-39) were used in the analysis. Specifically, factors pertaining to hyperactivity were chosen for correlation analysis. The 10-item Hyperactivity Index and the 8-item factor III Restless-Disorganised were used from the Parents Rating

Scale (Appendix B). The Hyperactivity Index and the Hyperactivity factor were used from the teachers rating scale. The factors mentioned above are constructs of item questions that correlate and are useful in assessing specific behaviours. The Hyperactivity index consists of 10 question items and was developed to provide an easily measured, empirical assessment of the extent to which the child performs behaviour that are usually considered as indicative of an underlying diagnosis of hyperkinesis (Conners, 1990). The Hyperactivity Index from the parent's scale and from the teacher's scale consists of the identical 10 items.

Continuous performance test

The Conners' Continuous Performance Test (CPT) version 1.0 is a 15 minute laboratory test involving the child's continuous responding to letters presented on a computer screen, with one-quarter of the stimuli consisting of a non target letter ('X') (Conners, 1994). This test is used to assess deficits in response Inhibition. The participants are scored on the number of omission and commission errors committed during the test. During this test, subjects are seated facing a computer screen for the whole duration test.

Actigraph

The actigraph is a portable ambulatory monitoring device the size of a wristwatch capable of detecting and recording movements. The actigraph used in this

study was designed and fabricated by Motionlogger Actigraph©, Ambulatory Monitoring, Ardsley NY. The model used was the BMA-32 set to the zero crossing method. On this setting, each time the actigraph is moved with an acceleration greater than 0.01g a voltage signal is emitted and compared to a reference signal. The number of times the reference signal is compared is accumulated until the end of the user defined epoch. Movements were recorded in 30-sec. epochs. At the end of each assessment, these data were downloaded by means of an interface unit into a software program (Action3; Ambulatory Monitoring Inc, 1996). This enabled us to visually inspect the data and calculate mean activity frequencies for discrete time periods. Mean activity is reported as the average movements per 30-sec (Appendix A). For additional details on the mechanics of an actigraph, consult the detailed description provided by Tyron, (1991). The actigraph was worn around the waist in a specifically designed pouch for 17 subjects. The remaining 21 subjects wore the actigraph on the non-dominant wrist as is recommended as an alternative to truncal recording (Tryon, 1991). The change from the waist to the wrist recording was made because the wrist recording was thought to be more sensitive to fidgeting particularly during sedentary structured testing situations. However, this change was made halfway through the study and as a result, the number of subjects wearing the actigraph on the wrist or waist was equal in the ADHD and control group.

Procedure

From start to finish data collection for this study spanned 18 months, ADHD and LNCG subjects were not assessed in any specific order. Prior to testing, both parent and child individually agreed to participate in this study and signed the appropriate consent and assent form respectively (Appendix B). Activity was measured using the actigraph for the entire duration of the assessment. This enabled us to determine the mean activity during discrete activities. The structured setting refers to periods in the research lab that consisted of a morning and afternoon session. The unstructured setting refers to the time the parent and child break for lunch. In total four time frames or activities were delineated for analysis: Overall, Structured, Unstructured, and CPT. Activity recorded during the CPT is embedded within the structured setting. Activity levels were also determined for the morning session and the afternoon session. The purpose of this division was to assess not only situational differences in activity but also temporal variations of activity across the groups.

Results

Actigraphic measures

The sample as a whole $\underline{n} = 37$ was analysed for differences in activity as measured by the actigraph. An alpha level of .05 was used for all statistical tests. Actigraphic recording divided up into two time frames: the structured time and unstructured time. During the structured time, the subjects were at the research laboratory and were participating in various psychometric measures and questionnaires. The unstructured time refers to the break during which the child and the parent/guardian left the premises for lunch. Actigraphic measures were analysed as overall, referring to the entire testing session, structured and unstructured. The actigraphic data collected during the administration of the 15-minute Continuous Performance Test (CPT) were also analysed. It must be noted that the CPT is a setting nested within the structured setting.

Using a one group (sample) by four settings (Overall, Structured, Unstructured and CPT) repeated measures design, a general linear model Anova was performed. Mean activity for all subjects and subgroup across all settings are presented in Table 1. All actigraphic measurements are presented as the average number of detectable movement per 30 sec. time epochs converted to mean activity for the specified duration of the activity. The results from the Anova indicated that the main effect (different settings) was significantly different.

Table 1. Activity measures by ADHD status and setting

		Setting: Mean duration (SD)			Main Effects: F Values (df)	
	Overall 4h45min (39.56)	Structured 3h41min (58.9)	Unstructured 51min (15.89)	CPT 15min	Contrast 1 Structured vs. Unstructured	Contrast 2 Structured vs. CPT
Whole Sample						
Mean	95.75	90.59	117.26	80.01	10.73*	6.64*
(SD)	(25.54)	(27.51)	(22.26)	(30.26)	(1,33)	(1,29)
n	37	37	33	34		
ADHD						
Mean	97.68	93.02	118.62	84.90		
(SD)	(32.71)	(34.47)	(28.50)	(32.02)		
n	19	19	18	17		
ADHD/+med						
Mean	88.98	83.74	111.15	79.78		
(SD)	(23.38)	(26.40)	(11.83)	(30.54)		
n	12	12	11	12		
ADHD/-med						
Mean	112.61	108.93	130.36	97.18		
(SD)	(42.37)	(42.66)	(42.47)	(35.63)		
n	7	7	7	5		
LNCG						
Mean	93.71	88.03	115.63	75.11		
(SD)	(15.51)	(18.18)	(11.88)	(10.51)		
n	18	18	15	17		

Note: ADHD = Attention Deficit Hyperactivity Disorder;

LNCG = Local Normative Comparison Group;

ADHD/+med = ADHD subjects receiving medication during actigraphic data collection;

ADHD/-med = ADHD subjects not receiving medication during actigraphic data collection; Structured = time in the laboratory engaged in specific tasks;

Unstructured = lunch break away from laboratory;

CPT = Continuous Performance Test.

*$p < .05$.

Post-Hoc comparisons revealed that actigraphic recordings significantly differentiated each setting. For the structured versus unstructured contrast $F(1,33) = 10.73$ $p < .002$. For the structured versus CPT contrast $F(1,29) = 6.64$, $p = .015$. Activity measured by the actigraph was the lowest during the administration of the CPT ($M = 80.01$, $SD = 30.26$) and was the highest during the unstructured setting ($M = 117.26$, $SD = 22.26$). Overall activity was composed of both the structured and unstructured setting and as a result was highly correlated with the activity scores during the structured setting. Thus, for this analysis, mean actigraphic scores calculated for the overall setting were omitted.

An analysis of variance was performed comparing mean activity across all settings for the ADHD and LNCG subjects. The results indicated that the main effect of group status and setting were non-significant, $F(1,35) = .219$ $p = .643$. The ADHD subjects were divided into those on medication the day of assessment (ADHD/+med) and those not receiving medication (ADHD/-med). An analysis of variance was repeated using three groups LNCG, ADHD/+med and ADHD/-med. Again the Anova failed to detect a significant difference between the groups,

$F(2,34) = 2.133$ $p = .134$

Even though the interaction of Group versus Setting was not significant, we examined the simple effects for each pairing. Post-hoc comparisons using least Significant Difference (LSD) test were used to illustrate the relative difference between each pairing of groups.

For the LNCG versus ADHD/+med comparison SE = 9.23, p = 612. For the LNCG and ADHD/-med comparison SE = 11.04, p = .096, and finally the ADHD/+med and ADHD/-med comparison SE = 11.78, p = .053. In general, differences in activity levels during specific settings were recognised using actigraph scores. Differences in mean activity between subgroups on the other hand were not identifiable using the actigraph.

Wrist-Waist

Actigraphic data was collected from two locations, 21 subjects wore the actigraph on the wrist while 17 wore the actigraph around the waist. When both groups of subjects were compared for differences in activity levels using an independent t-test, a significant difference was detected for the Structured setting $t(35) = 3.155$, $p = .003$ but not for the unstructured setting $t(31) = 1.586$, $p = .123$. Apart from differences in mean activity during the unstructured setting, actigraphic scores recorded from the waist were consistently lower than recordings made from the wrist. A chi-square test showed that subjects wearing the actigraph on the wrist and waist were equally partitioned in the LNCG and ADHD groups χ_2 (1, n = 37) 1.076, $p > .05$. When wrist and waist recordings were analysed separately, Anova and correlation results were unaffected by the location of the actigraph. For these above reasons, all actigraphic data was pooled.

AM-PM

Actigraphic data collected during the structured session was also separated as an AM session and PM session and analysed for differences. Mean activity in the afternoon was consistently lower for all groups in the afternoon than in the morning. This difference however did not reach significance. The LNCG displayed the greatest decrease in mean activity $t(14) = 1.749$ $p = .101$ and the ADHD/-med demonstrated the least $t(9) = .163$ $p = .912$. It is important to mention that the mean duration of the afternoon structured session (M = 1h46 min, SD =36.72) was generally shorter than the morning session (M = 2h42 min, SD = 34.48) for most subjects.

Correlation Analysis

Correlations between actigraphic measures and parent and teacher ratings of hyperactivity across all settings are shown on Tables 2 and 3 respectively. It should be noted that these ratings were based on the child's behaviour over the previous month. The parent ratings on the factor III Restless-Disorganised were significantly correlated with actigraphic scores for the LNCG collected during the CPT $r = .643$, $p = .005$. In all other settings however, factor III Restless-Disorganised was not

correlated with the actigraphic scores of any group. The parent ratings on the 10-item Hyperactivity Index did not correlate with actigraphic measures of any group for all settings.

The Teacher ratings on the Hyperactivity Index significantly correlated with actigraphic scores for the whole sample and the ADHD subjects during both the structured and unstructured settings. Measures of activity during the CPT however did not correlate with the Hyperactivity factor or the Hyperactivity Index.

Table 2. Correlation between actigraphic measures and Parent ratings of hyperactivity across settings

	Parent							
	Factor III Restless-Disorganised				Hyperactivity Index			
	Overall	Structured	Unstructured	CPT	Overall	Structured	Unstructured	CPT
Whole								
Correlation	-.106	-.083	-.099	.103	.000	.020	-.007	.130
Sig.	.539	.631	.585	.569	.999	.909	.967	.462
N	37	37	33	34	37	37	33	34
ADHD								
Correlation	-.239	-.206	-.208	-.224	-.192	-.169	-.168	-.216
Sig.	.340	.413	.408	.405	.431	.489	.505	.404
N	19	19	18	17	19	19	18	17
ADHD/+med								
Correlation	-.001	.032	-.048	-.203	-.154	-.125	-.276	-.262
Sig.	.998	.925	.888	.548	.634	.700	.412	.410
N	12	12	12	12	12	12	12	12
ADHD/-med								
Correlation	-.433	-.413	-.304	-.293	-.543	-.533	-.355	-.349
Sig.	.332	.357	.508	.632	.208	.218	.434	.565
N	7	7	7	5	7	7	7	5
LNCG								
Correlation	.199	.125	.184	.643**	.300	.269	.298	.408
Sig.	.429	.620	.513	.005	.227	.280	.280	.104
N	18	18	15	17	18	18	15	17

Note: ADHD = Attention Deficit Hyperactivity Disorder;

LNCG = Local Normative Comparison Group;

ADHD/+med = ADHD subjects receiving medication during actigraphic data collection;

ADHD/-med = ADHD subjects not receiving medication during actigraphic data collection;

Parent Hyperactivity Index and Factor III Restless-Disorganised are from the CPRS-93.

The specific items on these factors can be found in Appendix C.

*p < .05. **p < .001.

Table 3 Correlation between actigraphic measures and Teacher ratings of hyperactivity across settings

	Teacher							
	Hyperactivity Index				Hyperactivity Factor			
	Overall	Structured	Unstructured	CPT	Overall	Structured	Unstructured	CPT
Whole								
Correlation	.377*	.359*	.446*	.244	.192	.177	.279	.065
Sig.	.023	.032	.009	.172	.262	.301	.116	.721
N	36	36	33	33	36	36	33	33
ADHD								
Correlation	.494*	.479*	.532*	.172	.235	.219	301	-.110
Sig.	.037	.044	.023	.525	.348	.382	.225	.685
N	18	18	18	16	18	18	18	16
ADHD/+med								
Correlation	.079	.040	.293	-.242	-.002	-.047	.419	-.348
Sig.	.817	.907	.381	.473	.995	.891	.200	.294
N	11	11	11	11	11	11	11	11
ADHD/-med								
Correlation	.550	.554	.524	.402	.168	.171	.124	.015
Sig.	.201	.197	.227	.502	.719	.714	.791	.981
N	7	7	7	5	7	7	7	5
LNCG								
Correlation	.153	.118	.288	.226	.052	.024	233	.153
Sig.	.543	.640	.298	.384	.839	.926	.404	.559
N	18	18	15	17	18	18	15	17

Note: ADHD = Attention Deficit Hyperactivity Disorder;

LNCG = Local Normative Comparison Group;

ADHD/+med = ADHD subjects receiving medication during actigraphic data collection;

ADHD/-med = ADHD subjects not receiving medication during actigraphic data collection;

Hyperactivity Index and Hyperactivity Factor are from the CTRS-39.

The specific items on these factors can be found in Appendix B.

*$p < .05$. **$p < .001$.

Parent/Teacher Ratings

Although not reported in the table, the ratings on the two factors from the same informant were highly correlated. The parental Hyperactivity Index and Factor III Restless-Disorganised, $r = .821$, $p < .001$, and the teacher Hyperactivity Index with the Hyperactivity factor $r = .888$ $p < .001$.

Correlations between parent and teacher ratings of hyperactivity are presented in Table 4. The main significant correlations between the parent and teacher ratings were found for the LNCG subjects and not for the ADHD group or ADHD subgroups. Specifically for the LNCG subjects, the parent rating on factor III Restless-Disorganised correlated significantly with teacher ratings on the Hyperactivity Index $r = .483$, $p < .042$ and almost significantly with the teacher ratings on the Hyperactivity factor $r = .466$, $p < .051$. Similarly the parent rating on the Hyperactivity Index correlated significantly with the teacher rating on the Hyperactivity factor and the teacher Hyperactivity Index $r = .798$, $p < .000$, and $r = .616$ $p < .006$.

Table 4. Correlation between Parent and Teacher ratings of hyperactivity for the whole sample and subgroups

	Parent Factor III / Teacher HI	Parent HI/ Teacher HI	Parent Factor III/ Teacher HA	Parent HI / Teacher HA
Whole Sample				
Correlation	.204	.486**	.206	.418*
Sig.	.233	.002	.229	.010
N	37	37	37	37
ADHD				
Correlation	-.195	.037	-.207	.046
Sig.	.438	.881	.409	.852
N	19	19	19	19
ADHD/+med				
Correlation	.044	.024	.140	.126
Sig.	.898	.942	.681	.697
N	12	12	12	12
ADHD/-med				
Correlation	-.435	-.289	-.655	-.456
Sig.	.330	.530	.110	.304
n	7	7	7	7
LNCG				
Correlation	.483*	.798**	.466	.616**
Sig.	.042	.000	.051	.006
n	18	18	18	18

Note: ADHD = Attention Deficit Hyperactivity Disorder;

LNCG = Local Normative Comparison Group;

ADHD/+med = ADHD subjects receiving medication during actigraphic data collection;

ADHD/-med = ADHD subjects not receiving medication during actigraphic data collection;

Parent HI = Hyperactivity Index and Factor III Restless-Disorganised are from the CPRS-93.

Teacher HI = Hyperactivity Index and HA = Hyperactivity factor are from the CTRS-39.

The specific items on these scales can be found in Appendix C.

*p < .05. **p < .001.

Discussion

Actigraph

Actigraphic recordings differentiated activity level during different settings. As expected, during unstructured setting, mean activity for the sample was the greatest and during structured setting mean activity was significantly lower ($p < .001$) Activity level recorded during the administration of the CPT, an activity that requires very little motoric movement, was differentiated from the structured setting as a whole. This result is congruent with studies that have used observational and actigraph measures to show a decrease in activity during tasks that require increased focused attention (Stevens, 1978; Porrino, 1983a; Taylor, 1998). This result also lends validity to the actigraph in its ability to detect subtle differences in activity in a controlled environment.

There was no difference in activity level when we compared the LNCG and the ADHD subject across all settings. This result is likely due to the fact that 12 of the 19 ADHD subjects received medication that day and stimulant medication decreases activity in ADHD children to levels observed in control subjects (Porrino 1983a, Borcherding 1989). Interestingly, the mean activity level of the ADHD subjects that received medication that morning exhibited the lowest mean activity of

any group overall and during the structured and structured settings.

The non-medicated ADHD subjects were the most active in all settings. However, due to the small number of subjects in this group, differences in mean activity did not reach the level of significance. When we compared mean activity for the LNCG (mean activity (SD) = 88.03 (18.18)) to the non-medicated ADHD subgroup (mean activity (SD) = 108.93 (42.66)), the greatest difference was observed during structured time p = .093. The smallest difference in mean activity was observed during the unstructured setting p = .213, LNCG (mean activity (SD) = 115.63 (11.88)) non-medicated ADHD (mean activity (SD) = 130.36 (42.47)). This trend is consistent with studies that have shown ADHD children to appear more active compared to unaffected children of the same age except during activities that involved little structure such as free play. During such activities, differences in activity between ADHD and controls are less marked and generally disappear (Porrino, 1983a; Borcherding, 1989).

Actigraph & Parent Ratings

The prediction of a positive correlation between parent ratings and activity during unstructured settings was not supported by our results. In fact parent ratings on the two factors (Factor III Restless disorganised and Hyperactivity Index) were not correlated with any activity measure of any group across all settings. There was however one exception, factor III Restless-Disorganised correlated with activity

scores recorded during the CPT for the LNCG. The correlation between the two measures is most likely due to the fact that unaffected children received very low ratings on items pertaining to activity and during the CPT this group exhibited the lowest mean activity and associated standard deviation SD (10.51). Thus this correlation may be the result of having two measurements that are relatively stable. This finding and the lack of correlation with other groups may also indicate a lack of sensitivity factor III Restless Disorganised has in assessing discrete changes in activity levels. The parental ratings on this factor may reflect a more global impression of the child's behaviour rather than their impression on specific symptoms. Thus parents appear to rate the deviancy of the hyperactivity and not the activity levels per se. This is consistent with conclusions that parental ratings of hyperactivity do not agree with clinic observations (Sanberg, 1986) or actigraph readings (Hole, 1986).

Of the four factors chosen for comparison in this study, the 8-item Restless-Disorganised factor III from the parents' rating scale contains the most items pertaining directly to hyperactivity (Appendix B). The items in question are (1) Restless or overactive, (2) Constantly fidgeting, (3) Always climbing, (4) Acts as if driven by a motor. The remaining four items pertain to other problem behaviours: (5) Excitable, overactive, (6) A very early riser, (7) Demands must be met immediately-easily frustrated, (8) Cannot stand too much excitement. The lack of correlation of actigraphic score and factor III Restless Disorganised may be indicative of a lack of

relevance these items may have in older children. Children rated in this study were between the ages of 10 and 13 years and some of the behaviours described on this factor may be more relevant to younger children such as items 3, 4 and 6. It is well established that activity level changes over the age span and almost all methods of measuring activity show a decline of activity level with age (Taylor, 1998; Conners, 1985). This decrease is mainly of gross motor hyperactivity involving large muscles. As the child matures, the hyperactivity takes the form of a lot small muscle versus large muscle movements such as shifting positions in one's chair and fidgeting as opposed to getting up and running around (Hechtman, 1991; Milich, 1982). Thus the items on this scale may not be particularly sensitive to the type of activity seen in these children at this age in these settings.

Actigraph & Teacher Ratings

The 17-item Hyperactivity factor from the teachers' rating scale was not correlated with the activity level of any group across all settings (Appendix B). Items from this scale address a number of problem behaviours associated with hyperactivity such as aggressiveness, oppositionality and disruptiveness as opposed to activity per se. Some items also pertain to distractibility and inattention. While some of the behaviours listed on this factor have shown a high correlation with increased activity such as impulsiveness, the broad scope of behaviours on this factor may be the reason for the lack of relationship with actigraphic scores (Taylor, 1998).

Hyperactivity index

Originally designed to identify children with an underlying diagnosis of hyperkinesis, the 10-item hyperactivity index has evolved into a tool that groups items that pertain to motoric overactivity or behaviours associated with hyperactivity. Some of these items include, (1) Constantly fidgeting, (2) Restless or overactive, (3) Temper outburst, (4) explosive and unpredictable behaviour. Other items pertain to behaviours associated with impulsivity and inattention, (5) Excitable, impulsive, (6) Inattentive, easily distracted, (7) Fails to finish things s/he starts-short attention span, (8) Demands must be met immediately-easily frustrated. We found that the parent ratings of hyperactivity index did not correlated with the activity level of any group across all settings. The teacher's rating on identical items however significantly correlated with the sample as a whole and the ADHD group for both the structured and unstructured settings. This finding may indicate that the problem behaviours listed on the hyperactivity index may be more relevant in a classroom setting for children with ADHD. For instance, children with ADHD appear less active in one to one situations, in which they receive a great deal of attention. In group situations where individual attention is more scant and distractions more prevalent, these problem behaviours are more likely to be expressed (Barkley, 1997,1998). Thus, in the home setting many of the problem behaviours may not be as evident or impairing as in a classroom setting. It may also be that teachers are better than parents at rating

children behaviours. In fact the DSM-III (American Psychiatric Association, 1980) suggested that primary consideration should be given to teacher's reports. Due to their extensive contact with children in a variety of structured and unstructured settings, and their knowledge of age appropriate skills and behaviours, teachers provide more valid information for both clinical and research purposes (Shelton & Barkley, 1995).

Parent/teacher reports

Our finding of a lack of correlation between parent and teacher ratings is consistent with research findings of low correlation between different types of informants (Achenbach, 1987). However activity ratings from both parental and teacher factors significantly correlated for the activity score LNCG. This finding may be explained by the fact that unaffected children display very few of the problem behaviours listed in each scale in both the home and school setting. As a result, these children received a low rating from both parents and teachers. This leads us to the lack of correlation between informants for the ADHD group. The lack of correlation between parent and teacher ratings of children with ADHD may be due to the fact that the demands and expectations of children are different at home than at school. The factors that elicit problem behaviours in the classroom such as interactions with peers, the demand for sustained attention and the lack of direct and immediate attention, may not as meaningful at home.

Conclusion

The main limitation of this study was the small sample size. In order to accurately analyse the activity of the subjects, it was necessary to divide the ADHD subjects into subgroups that resulted in a small non-medicated ADHD subsample. Because of this shortcoming, we were unable to confirm some of our expectations statistically. Another limitation lies in the fact that that the measurements were done in a laboratory setting. Had *in vivo* recordings of motor activities in school and home settings been made, the measures would have provided a better validation of parent-rated and teacher-rated hyperactivity.

The results of this study indicate that while rating scales may provided important information regarding the overall picture of the ADHD child, specific information on hyperactivity may be difficult to assess from these subjective rating scales. The aversive features of motor excess make it difficult to write items assessing hyperactivity that will not also be responded to when parents and teachers rate aggressiveness and impulsivity. Instrumented measurements of activity have the advantage of being objective and responding to physical forces associated with the site of attachment and not to the broader social implication associated with motor excess (Tryon, 1993). This unidimensionality may also be viewed as a limitation. The activity measured by the actigraph does not give any indication of the appropriateness, goal directedness, the purpose or disruptive nature of the activity.

For these reasons, rating scales remain important tools in the diagnosis of ADHD and a number of other psychiatric disorders. While these ratings scales will always have a subjective element to them, impressions and judgements are the elements that will lead to a diagnosis. Often the global impression of parents and teachers is precisely what clinicians and researchers are seeking. However, variations between reports by different informants argue for assessment in terms of multiple axes. The use of the actigraph as a complementary tool in the assessment of children presenting with ADHD has the potential to confirm the presence or absence of hyperactivity in more than one setting. Presently, actigraphic technology is mainly used for research purposes and not in clinical settings. The clinician interested in assessing the hyperactivity dimension of patients should seek information from as many informants that have contact with the child from several different settings. Future uses of actigraphic measures as an adjunct to current approaches are a realistic possibility as clinicians and families are seeking more objective measures in the assessment and treatment process.

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Appendix A

Sample Actigraphic display

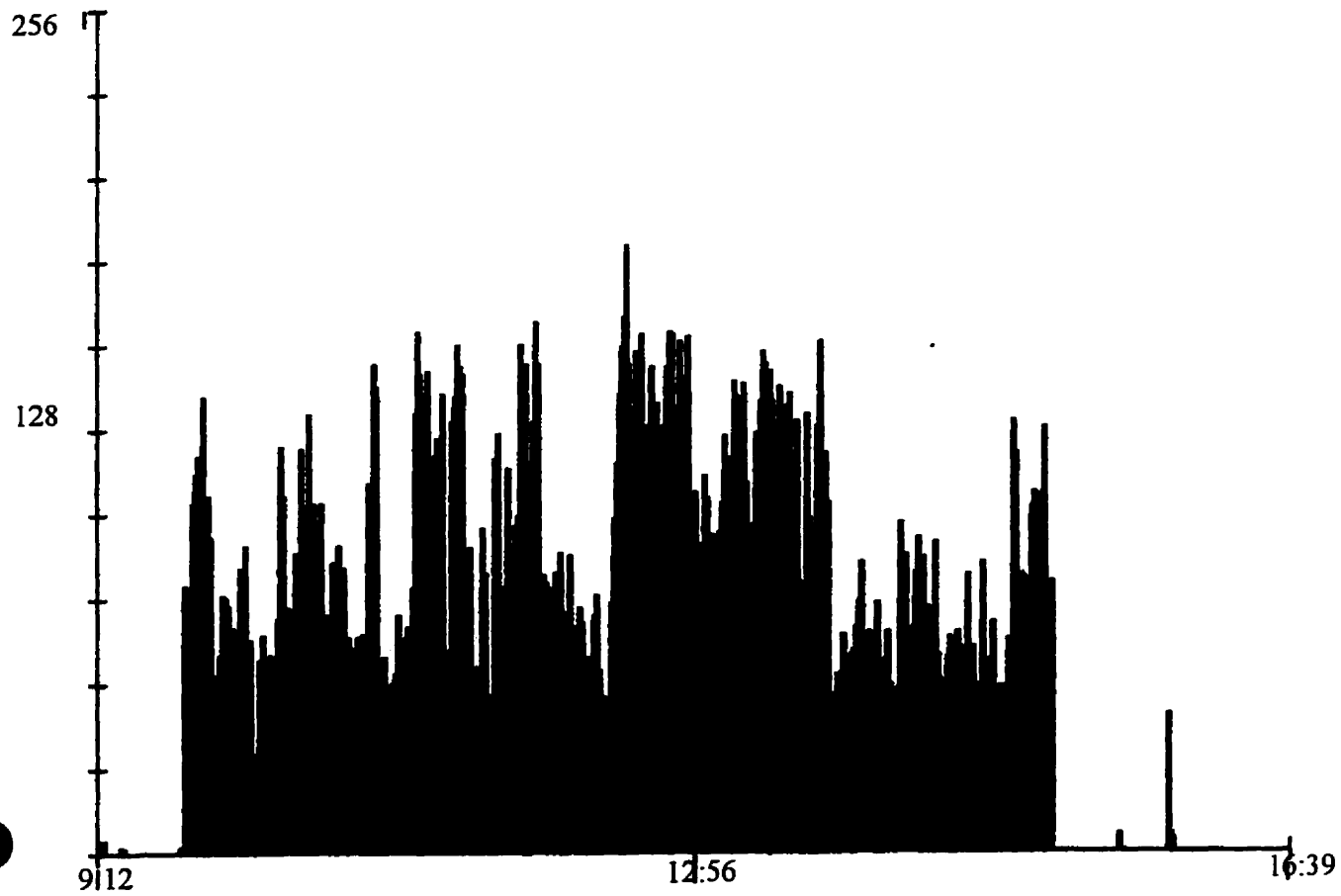
Sample Actigraphic display

12 year old male ADHD subject (Medicated)

Structured setting: AM 9:45 – 12:34
PM 13:35 – 15:06

Unstructured Setting: 12:34 – 13:35

X axis: time
Y axis: Activity counts per 30 sec. epochs



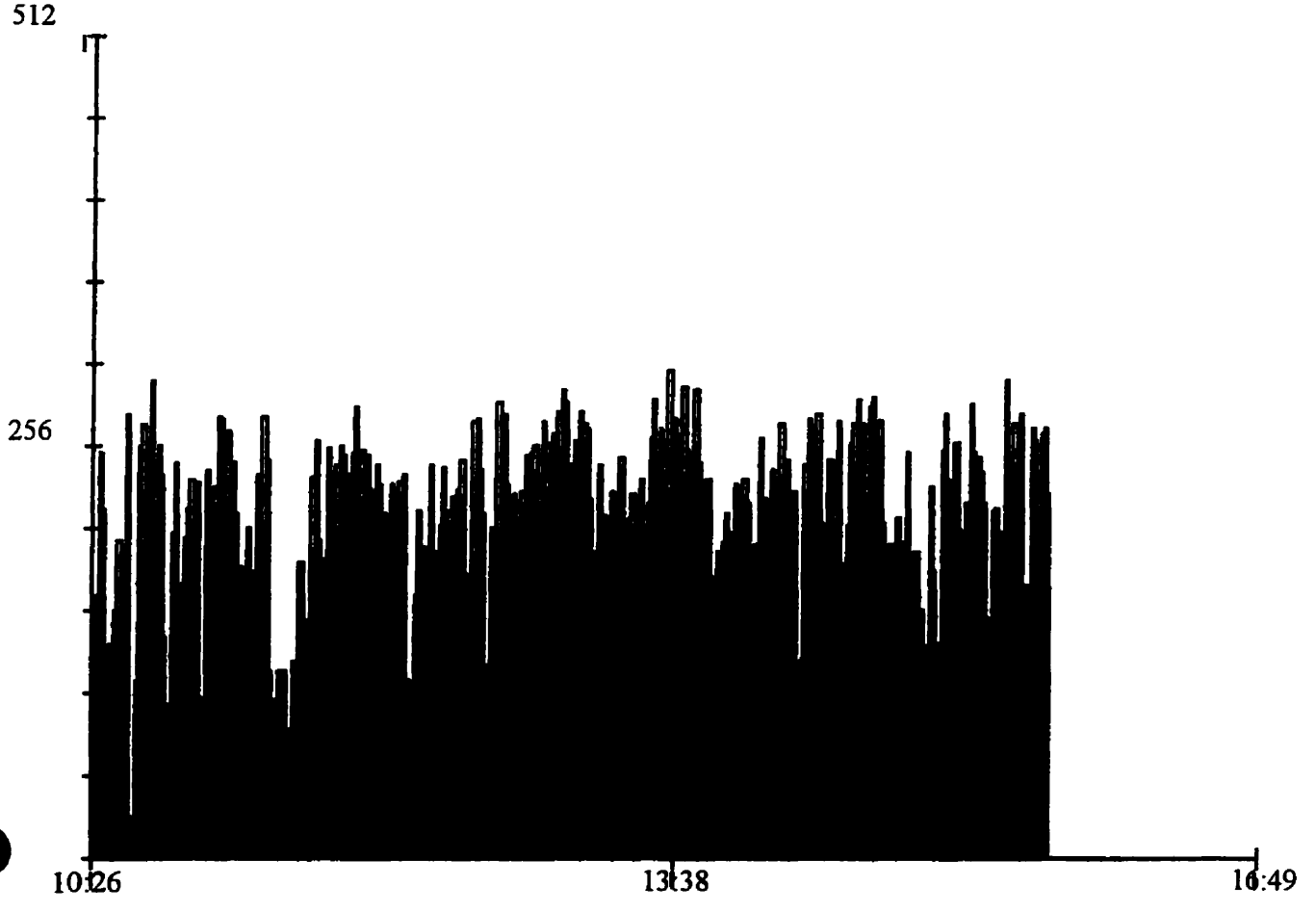
Sample Actigraphic display

12 year old male ADHD subject (Non-medicated)

Structured setting: AM 10:24 – 12.28
PM 13:21 – 15:42

Unstructured Setting: 12:29 – 13:21

X axis: time
Y axis: Activity counts per 30 sec. epochs



Appendix B

Parent consent form & Child assent form

Appendix C

Conners Parent Rating Scale version-93: Factor III
Conners Teacher Rating Scale version-39-Hyperactivity Factor
Hyperactivity Index

Conners Parent Rating Scale version-93

Factor III- Restless-Disorganized-8 items

1. Restless or overactive
2. Excitable, impulsive
3. Constantly fidgeting
4. Always climbing
5. A very early riser
6. Demands must be met immediately-easily frustrated
7. Cannot stand too much excitement
8. Acts as if driven by a motor

Hyperactivity Index-10 items

1. Disturbs other children
2. Restless or overactive
3. Excitable, impulsive
4. Temper outburst, explosive and unpredictable behaviour
5. Fails to finish things s/he starts-short attention span
6. Inattentive, easily distracted
7. Constantly fidgeting
8. Demands must be met immediately-easily frustrated
9. Cries often and easily
10. Mood changes quickly and drastically

Conners Teacher Rating Scale version-39

Hyperactivity factor: 17 items

1. Constantly fidgeting
2. Hums and makes other odd noises
3. demands must be met immediately-easily frustrated
4. coordination poor
5. restless or overactive
6. excitable, impulsive
7. inattentive, easly distracted
8. fails to finish things s/he starts-short attention span
9. daydreams
10. disturbs other children
11. quarrelsome
12. acts "smart"
13. appears to be easily led
14. teases other children or interferes with their activities
15. impudent
16. excessive demands for teacher's attention
17. Uncooperative

Teacher-Hyperactivity index-10 items

1. Constantly fidgeting
2. Demands must be met immediately-easily frustrated
3. Restless or overactive
4. Excitable, impulsive
5. Inattentive, easily distracted
6. Fails to finish things s/he starts-short attention span
7. Cries often and easily
8. Disturbs other children
9. Mood changes quickly and drastically
10. Temper outburst, explosive and unpredictable behaviour