



THE AUDITORY CONTINUOUS PERFORMANCE TEST AS PART OF AN ADHD TEST BATTERY

Stephanie R. Briggs, M.A.^{*}

Joseph J. House, Ph.D.^{***}

Robert W. Keith, Ph.D.^{*}

Ernest M. Weiler, Ph.D.^{**}

Introduction

Attention Deficit-Hyperactivity Disorder (ADHD) is one of the most common neurobehavioral disorders among children. It is prevalent in clinical settings, comprising about 50% of the child psychiatric population (Cantwell, 1996). Children with ADHD are generally described as having ongoing problems in the areas of inattention, impulsivity, and hyperactivity. Inattention may be described in terms of span of apprehension, alertness, arousal, selective distractibility, or sustained attention (Hale and Lewis, 1979). According to Douglas (1983), most inattention problems in children are manifested in the area of sustained attention or vigilance. Impulsive children are often described as responding quickly to situations without waiting for complete instructions or information. Often they make heedless or careless errors (Barkley, 1990). Hyperactivity refers to excessive

* Department of Otolaryngology, Division of Audiology, University of Cincinnati Medical Center.

** Communication Sciences Disorders, University of Cincinnati.

***Private practice, Minneapolis Minnesota.

or developmentally inappropriate levels of activity, which may be motor or visual in nature.

The Diagnostic and Statistical Manual, Fourth Edition (DSM-IV) sets forth criteria upon which diagnosis of ADHD is based. The DSM-IV defines two dimensions of behavior: inattention and hyperactivity-impulsivity. Three subtypes of ADHD are derived from these criteria. Having a preponderance of inattentive symptoms, but not hyperactive symptoms leads to diagnosis of ADHD-predominantly inattentive type. A preponderance of hyperactive symptoms without inattentive symptoms leads to diagnosis of ADHD-predominantly hyperactive-impulsive type. A preponderance of both types of symptoms leads to diagnosis of ADHD-combined type (APA, 1994). Diagnosis of ADHD is often based upon a combination of observation, interviews, and behavior rating scales completed by parents, children, teachers, and other professionals. In addition, vigilance tasks, either auditory or visual are often employed. In a vigilance test, the subject is required to maintain attention to a single source of input over time. Throughout the task, the subject identifies targets. For example, the Conners' Continuous Performance Test is a test of vigilance conducted in the visual mode. The subject watches a series of letters presented on a screen and responds by pressing a button either to a target letter, or a target series. In another situation, the subject is required to respond to any letter except the target letter (Conners, 1992).

The use of vigilance tests as measures of inattention and impulsivity is supported by research. Particularly useful are studies that either compare ADHD children both with and without medication such as methylphenidate (Ritalin). Many have indicated that children with ADHD made more errors of omission and commission than non-ADHD controls. Also, methylphenidate reduces other types of errors in ADHD children (Rapport, 1986; Sykes, 1973; Losier, 1996; Keith, 1991).

There are two types of errors on a vigilance test. Errors of omission occur when the subject fails to respond to a present target. Errors of commission occur when the subject responds in the absence of a target. It has been suggested that errors of omission are indicative of inattention and that errors of commission are indicative of impulsivity or hyperactivity. While most agree that omission errors indicate inattention, there are mixed opinions regarding commission errors. Some

have suggested that commission errors are not necessarily indicative of hyperactivity or impulsivity (Conners, 1992; Halperin, 1992; Halperin, 1988). Others suggest that commission errors do indicate impulsivity (Corkum, 1993).

The Auditory Continuous Performance Test (ACPT) (Keith, 1994) was developed to identify auditory attention deficit disorders in children. The test consists of a word identification task with monosyllable words presented to a child via an audiocassette. The child responds by raising his or her thumb when the target word (dog) is heard. The test duration is 11 minutes, including one presentation of the Trial Word List and the complete Test Word List. The resulting measure is independent of the observer bias that may be present in human observers performing other assessments. This does not suggest that the ACPT take the place of observation. Rather, the information from the ACPT can be used conjointly with information gathered from other sources to support diagnosis (Keith, 1994).

In a pilot validity study, it was found that the ACPT score was a predictor of ADHD diagnosis 70% of the time (Keith, 1994). Keith and Engineer (1991) examined the effects of methylphenidate on the auditory processing abilities of children with ADHD. Children with ADHD were assessed using an auditory vigilance test (a research version of the ACPT) both on and off the medication. Results indicated children in the medicated condition made significantly fewer errors of both omission and commission.

Despite these findings, the clinical usefulness of the ACPT for differential diagnosis has been questioned. Riccio (1996) compared the total error score (omissions plus commissions) from the ACPT of children with Central Auditory Processing Disorders (CAPD) and those of children with CAPD comorbid with ADHD. The findings indicated that the total error score was limited in its use for differential diagnosis of ADHD in conjunction with CAPD, as opposed to CAPD alone. The authors suggested that further research is needed in order to establish the degree to which the ACPT is able to predict the presence of ADHD. In addition, it was suggested that future research is needed to investigate ACPT performance differences in children with diagnoses of the three subtypes of ADHD.

This study investigated ACPT performance of children with two of the three subtypes of ADHD: ADHD, predominantly inattentive type and ADHD, combined type. Total error score as well as omission errors only and commission errors only were considered. We hypothesized that errors of omission, which are thought to indicate inattention, would be no more closely associated with a diagnosis of ADHD-predominantly inattentive type than with a diagnosis of ADHD-combined type (since both diagnoses require a preponderance of inattentive symptoms).

Secondly we hypothesized that errors of commission, which may indicate impulsivity, would be more closely associated with a diagnosis of ADHD-combined type than to a diagnosis of ADHD-predominantly inattentive type (since diagnosis of combined type requires meeting the criteria for hyperactivity and the diagnosis of inattentive type does not).

Finally, we hypothesized that total error score would also be more closely associated with the combined type diagnosis than the inattentive type diagnosis.

In this study we also attempted to contribute to the validity research concerning the ACPT. ACPT scores were examined and compared with scores obtained on children who were normal and those with ADHD previously reported by Keith (1994). Published ACPT age norms (Keith, 1994) were also be compared to mean scores obtained in the present study.

Not central to the study, but of interest was the relationship between errors of omission and commission on the ACPT and measures of attention and hyperactivity.

Method

Data was analyzed on 45 children who had been previously tested by an educational psychologist in private practice. The majority of children in this study were caucasian and were from middle class traditional two-parent or blended families. Subjects were from the St. Paul/Minneapolis metropolitan area. Referrals for testing were made either by school staff or family physicians. No child in this study was or had ever been on medication for the treatment of ADHD. All children had received a diagnosis of ADHD as a result of the testing. Twenty-nine

had a diagnosis of ADHD, combined type and 16 had a diagnosis of ADHD, predominantly inattentive type. Of the 45 children, 14 were female (31.2%) and 31 were male (68.8%). The age of subjects ranged from 6 to 11 years with a mean of 7.89 years. In compiling the data for this study, only cases of children from 6-11 years of age were considered as that is the age range for which the ACPT has normative data.

The test battery employed to assist in diagnosis included the ACPT and some or all of the following: ADHD Rating Scale, DSM-IV criteria, Child Behavior Checklist, Conners' Continuous Performance test, Conners' Teacher Rating Scale, Conners' Parent Rating Scale, and the Child Attention Profile.

Results

To examine the relationship between error scores and ADHD subtype, a one way between groups analysis of variance was conducted. The ANOVA was obtained using SPSS, version 7.5 pc software, as were all statistics. Subjects were grouped by diagnosis. There were 29 children in the ADHD, combined group and 16 children in the ADHD, inattentive group. Total error score was examined as a function of group membership. There was no significant difference between the two groups, $F(1,43)=1.351$, ns (see Figure 1). The number of omission errors was also examined as a function of group membership. Again, there was no significant difference between the groups, $F(1,43)=.349$, ns. There was also no significant difference between the two groups with respect to number of commission errors, $F(1,43)=2.16$, ns (see Figure 1).

A Pearson's Product Moment Correlation was calculated to examine the relationship between subject age and ACPT total error score. A significant correlation was observed, $r=.538$, $p<.05$, indicating score improvement as a function of age. Correlations were also observed between age and number of errors of omission, $r=.377$, $p<.05$; and between age and errors of commission, $r=.554$, $p<.05$. Again, older children made fewer errors.

In the original Keith (1994) study, the ACPT was accurate in diagnosing ADHD 70% of the time. For this sample, 86% of the children were accurately diagnosed by the ACPT (they were above the criterion total error score for their

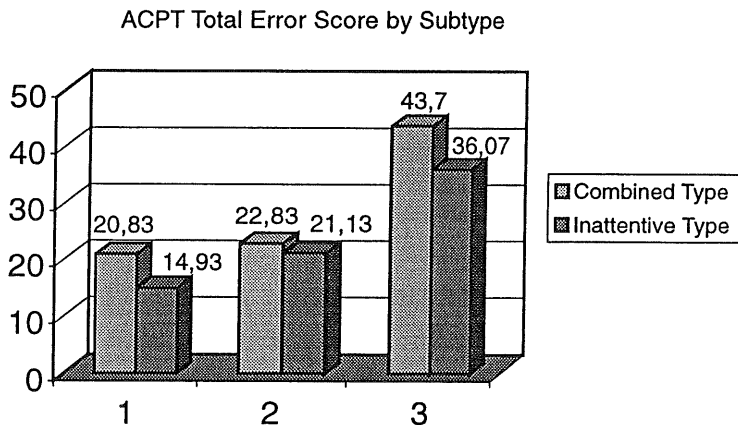


Figure 1. Comparison of the ACPT Total Error Score Between Two ADHD Subtypes

ages). Of these 39 children, 25 had ADHD, combined type, and 14 had ADHD, predominantly inattentive type. Of the 6 children that were not correctly identified by the ACPT, 4 had a diagnosis of ADHD combined type and 2 had a diagnosis of ADHD, predominantly inattentive type.

Mean scores for each age were compared with the means established by Keith (1994) for ADHD children and non-ADHD controls. Comparison was accomplished using a one sample versus population t test. There were no significant differences between ADHD children in the two studies at any age. For 6 year olds, $t(d.f.7)=2.011$, ns; for 7 year olds, $t(d.f.12)=.919$, ns; for 8 year olds, $t(d.f.8)=.442$, ns; for 9 year olds, $t(d.f.10)=1.747$, ns, and for 10 year olds, $t(d.f.4)=1.902$, ns.

There were significant differences between means reported here and those reported in Keith's (1994) non-ADHD control group. For 6 year olds, $t(d.f.7) 5.648, p<.05$, for 7 year olds, $t(d.f.12)=4.697, p<.05$; for 8 year olds, $t(d.f.8)=6.967, p<.05$; for 9 year olds, $t(d.f.10)=6.967$; for 10 year olds, $t(d.f.4)=6.973, p<.05$. There was only one 11-year-old subject in this study so no comparisons were drawn for that age group. See Figure 2 for comparison of means in the two studies. See Table 1 for all means and standard deviations from both studies.

The Auditory Continuous Performance Test as part of an ADHD test battery

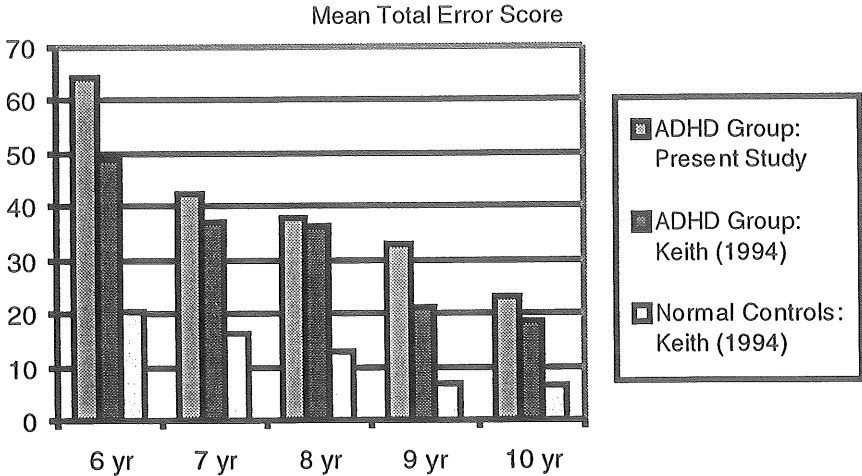


Figure 2. Comparison of Mean Total Error Score in the Present Study With Those Reported by Keith (1994)

Age	ADHD Mean Keith (1994)	Standard Deviation	Control Mean Keith (1994)	Standard Dev.	ADHD Mean Present Study	Standard Dev
6	48.8	30.9	20.4	16.3	64.5	22.08
7	37.2	23.2	16.2	10.5	42.31	20.03
8	36.4	24.9	12.8	9.1	38.00	10.85
9	21.2	13.5	6.9	6.3	32.81	22.06
10	18.5	13.6	6.5	7.3	23.00	5.29
11	15.3	18.5	6.8	4.7	-	-

Table 1. Means and Standard Deviations from the Results Reported by Keith (1994) and from the Present Study

Numbers of omission errors were compared with 3 measures of inattention using the Pearson's Product Moment Correlation. There was a significant relationship between number of omission errors on the ACPT and number of omission errors on the Conners' Continuous Performance test, $r=.319, p<.05$. There was no significant correlation between omission errors and the Attention Problems subscale of the Child Behavior Checklist, $r=.116, ns$. There was no signifi-

cant relationship between omission errors and score on the Inattentive-Passive subscale of the Conners' Teacher Rating Scale, $r=.216$, ns. Number of errors of commission were compared with 3 other measures in the test battery as well. There was no significant relationship between commission errors on the ACPT and commission errors on the Conners' Continuous Performance Test, $r=.067$, ns. There was a significant correlation between commission errors and the Impulsive-Hyperactive subscale of the Conners' Parent Rating Scale, $r=.319, p<.05$. There was no significant relationship between commission errors and the Hyperactivity Index from the Conners' Parent Rating Scale, $r=.212$, ns.

Discussion

Error scores on the ACPT were examined with respect to ADHD diagnosis. Hypotheses were made based upon the idea that omission errors are indicative of inattention and commission errors of hyperactivity or impulsivity. First, it was hypothesized that children with ADHD, inattentive type would not differ significantly from those with ADHD, combined type with respect to number of omissions. In fact, the two groups did not differ significantly. Diagnosis of both subtypes requires that the child meet the DSM-IV criteria for inattention. That the number of omission errors did not differ between the two groups suggests that omission errors may indicate inattention.

The second hypothesis was that children with ADHD, inattentive type and ADHD, combined type would differ in their total error scores and numbers of commission errors. This was not supported. The number of commission errors did not vary between the subtypes. Logic would seem to say that children with ADHD, combined type would make more commission errors since combined type has the hyperactive-impulsive component. That they do not differ suggests that number of commission errors cannot be considered as a measure of hyperactivity. Halperin (1988) examined omission and commission errors on a visual continuous performance task.

The task differed from the ACPT in mode of presentation and also in the nature of the target. In the visual task used, the children had to respond to "A followed by X". They were not simply picking out the target word as with the

ACPT. Since the tasks were different, direct comparison must be made with caution, but it is noteworthy that Halperin concluded that commission errors are not a homogeneous measure. Instead, they can be divided into error types, some of which seem to measure impulsivity, but not all. Conners, in the test manual for the Conners' CPT, cautions that commission errors and omission errors may reflect a mixture of different underlying processes. Therefore, it is misleading to think of them as direct measures of impulsivity or inattention (Conners, 1991).

There is another factor that may have influenced the number of errors made by the children in this study. That is, having one or more comorbid diagnoses did not exclude children from this study. A majority of the subjects did, in fact, have at least one other diagnosis in addition to ADHD. Research suggests that hyperactivity is specific to ADHD, but inattention is not. In other words, inattention may be a general symptom that is present in many disorders (Halperin 1992). If this is the case, then it seems reasonable to say that subjects, especially those with ADHD comorbid with other diagnoses, had ACPT scores that were more heavily influenced by their inattention than their hyperactivity.

Also, reaction time and vigilance decrement are other measures of continuous performance tests and these were examined here. Future research may include examining these measures across ADHD subtype. Also, in order to talk about what measures or does not measure impulsivity or hyperactivity, it would be helpful to include a group of children with ADHD, predominantly impulsive-hyperactive type.

One of the stated purposes of this study was to supplement the validity research by Keith (1994). First, with regard to age, it was found that older children made fewer errors. This is consistent with the earlier findings and it supports the current method of raising the criterion score on the ACPT as a function of age. Mean age scores were compared between the ADHD groups in the two studies. The results of the current study are very consistent with the results of Keith's (1994) work. The means reported by Keith appear to be accurate and generalizable.

Keith (1994) stated that the ACPT was accurate in diagnosing ADHD 70% of the time. Riccio (1996) questioned the ability of the ACPT to assess the presence or absence of ADHD. In this study, 86% of the children were accurately

diagnosed by the ACPT. The percentages reported in these two studies cannot be directly compared due to design differences, however, the current findings support the ACPT as an accurate predictor of ADHD. With regard to differential diagnosis between ADHD and CAPD, more research is needed. It is true that there are overlapping symptoms, however, the overlapping symptoms differ in importance for diagnosis. For example, in a recent survey of audiologists and pediatricians, inattention and distractibility were ranked as the number one and number two symptoms for ADHD. They were ranked seven and six for importance in CAPD (Chermak, 1998). The ACPT, a measure of auditory attention, would seem to be useful in distinguishing between CAPD and ADHD. Again, more research is needed in this area.

Not central to this study was the relationship between ACPT omission and commission errors with other measures in the test battery. In comparison with the Conners' CPT, there was a relationship between omission errors on the two tests, but not commission errors. Auditory vigilance tasks have been found to be more difficult than visual tasks for non-ADHD individuals (Baker, 1995) and for hyperactive children (Sykes, 1973) which may contribute to the lack of relationship between commission errors on the two tests. Direct comparison is difficult because these are two different tests as opposed to being auditory and visual forms of the same test.

In comparison with other measures, there was no significant relationship between omission errors on the ACPT and with the Attention Problems subscale of the CBCL or the Inattentive-Passive subscale of the Conners' Teacher Rating Scale. There was not a significant relationship between commission errors and the Impulsive-Hyperactive score on the Conners' Parent Rating Scale. This may indicate that commission errors have more to do with impulsivity than with hyperactivity.

It should be noted that there were some weaknesses in this study. First, many of the children in this sample had other diagnoses comorbid with ADHD. Second, only two of the ADHD subtypes were examined due to lack of available subjects with ADHD, predominantly hyperactive-impulsive type. Finally, there were not equal numbers of subjects in each ADHD subtype group and the predominantly inattentive group was rather small. Future researchers should attempt

to control for comorbidity. Attempts should also be made to include equal numbers of children with all three of the subtypes of ADHD.

In summary, the results of this study suggest that number of errors on the ACPT (omission, commission and total errors) do not differ between the two subtypes of ADHD considered here. Referring to an error of omission as an inattention error is supported, but referring to an error of commission as an impulsive error is not supported. Despite the fact that error type does not necessarily predict the subtype of ADHD, the ACPT does seem to predict the presence of ADHD and may thus be considered a useful part of a test battery for ADHD.

Abstract

The Auditory Continuous Performance Test (ACPT) is used in the diagnosis of Attention Deficit Hyperactivity Disorder. In this auditory vigilance task, omission errors and commission errors are tallied and combined into a Total Error Score. Some believe that errors of omission are indicative of inattention and commission errors of hyperactivity or impulsivity. This study attempted to determine if errors of omission and commission are measures of inattention and hyperactivity/impulsivity, respectively. Forty-five children with ADHD were given a test battery that included the ACPT. Two of the three ADHD subtypes were represented (ADHD, predominantly inattentive type and ADHD, combined type). Numbers of both types of errors were examined, as was Total Error Score to detect if differences existed between the two subtypes. Differences did not exist, suggesting that omission errors are indicative of inattention, but commission errors do not necessarily suggest the presence of hyperactivity or impulsivity. Finally, the initial validity research done by Keith (1994) was compared with results of this study and was supported.

Key-words: attention deficit, hyperactivity, auditory perception.

Resumo

O Teste ACPT (Auditory Continuous Performance Test) é utilizado no diagnóstico de distúrbio de atenção e hiperatividade (Attention Deficit Hyperactivity

Disorder). Nesta tarefa de vigilância auditiva, os erros de omissão e comissão são reunidos em uma tabela geral de erros. Alguns acreditam que os erros de omissão são indicativos de falta de atenção, e os erros de comissão indicativos de hiperatividade ou impulsividade. Este estudo procurou determinar se os erros de omissão e comissão são medidas de falta de atenção e hiperatividade/impulsividade, respectivamente. Quarenta e cinco crianças com ADHD passaram por uma bateria de testes incluindo o ACPT. Dois dos três subtipos de ADHD foram encontrados (ADHD, predominantemente falta de atenção, e ADHD, tipo combinado). O número do dois tipos de erros foi examinado, assim como a tabela geral de erros para detectar se existiam diferenças entre os dois subtipos. Não existiram diferenças, sugerindo que os erros de omissão são indicativos de falta de atenção, porém os erros de comissão não indicam necessariamente a presença de hiperatividade ou impulsividade. Finalmente, a pesquisa inicial de validade feita por Keith (1994) foi confirmada quando comparada com os resultados deste estudo.

Palavras-chave: deficit de atenção, hiperatividade, percepção auditiva.

References

- AMERICAN PSYCHIATRIC ASSOCIATION (1994). *Diagnostic and statistical manual of mental Disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- BAKER, D. B., TAYLOR, C. J., & LEYVA, C. (1995). Continuous Performance Tests: a comparison of modalities. *Journal of Clinical Psychology*, 51(4), 548-551.
- BARKLEY, R. A. (1990). *Attention deficit-hyperactivity disorder: a handbook for diagnosis and treatment*. New York, Guilford Press.
- CANTWELL, D. P. (1996). ADD- a review of the past 10 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 35(8), 978-987.
- CHERMAK, G. D., SOMERS, E. K., & SEIKEL, J. A. (1998). Behavioral signs of central auditory processing disorder and attention deficit hyperactivity disorder. *Journal of the American Academy of Audiology*, 9, 78-84.

The Auditory Continuous Performance Test as part of an ADHD test battery

- CONNERS, K. C. (1992). *Conners Continuous Performance Test computer program 3.0 user's manual*. Canada: Multi-Health Systems, Inc.
- CORKUM, P. V. & SIEGEL, L. S. (1993). Is the continuous performance task a valuable research test for use with children with attention deficit disorder? *Journal of Child Psychology & Psychiatry & Allied Disciplines*, 34(7), 1217-1239.
- DOUGLAS, V. I. (1983). Attention and cognitive problems. In M. Rutter (Ed), *Developmental Neuropsychiatry*, 280-329. New York, Guilford Press.
- HALE, G. A. & LEWIS, M. (1979). *Attention and cognitive development*. New York, Plenum.
- HALPERIN, J. M., et al. (1988). Differential assessment of attention and impulsivity in children. *Journal of the Academy of Child and Adolescent Psychiatry*, 27(3), 326-329.
- HALPERIN, J. M., et al. (1992). Specificity of inattention, impulsivity, hyperactivity to the diagnosis of attention deficit hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 31(2), 190-196.
- KEITH, R. W. (1994). *The Auditory Continuous Performance Test*. San Antonio, TX: Psychological Corp.
- KEITH, R. W. & ENGINEER, P. (1991). Effects of methylphenidate on the auditory processing abilities of children with attention deficit hyperactivity disorder. *Journal of Learning Disabilities*, 24(20), 630-636.
- LOSIER, B. J., McGRATH, P. J., & KLEIN, R. M. (1996). Error patterns on the continuous performance test in non-medicated and medicated samples of children with and without ADHD: a meta-analytic review. *Journal of Child Psychology & Psychiatry & Allied Disciplines*, 37(8), 971-987.
- RAPPORT, M. D., DuPAUL, G. S., & JONES, J. T. (1986). Comparing classroom and clinic measures of attention deficit disorder: differential, idiosyncratic, and dose-response effects of methylphenidate. *Journal of Consulting and Clinical Psychology*. 54(3)m 334-341.
- RICCIO, C. A., COHEN, M. J., HYND, G. W., & KEITH, R. W. (1996). Validity of the auditory continuous performance test in differentiating central

Stephanie R. Briggs, Joseph J. House, Robert W. Keith e Ernest M. Weiler

auditory processing disorders with and without ADHD. *Journal of Learning Disabilities*, 29(5), 561-566.

SYKES, D. H. (1973). Sustained attention in hyperactive children. *Journal of Child Psychology and Psychiatry*, 14, 213-220.

Recebido em jan/99; aprovado em mar/99