

The intellectual and academic performance of adolescents contaminated by lead: relation with social skills

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Abstract

This study investigated the impact of blood lead level on intellectual (IQ) and academic performance, four years after blood contamination through lead poisoning, as well as on behavior problems and social skills, eight years after the poisoning. Fifty-four adolescents participated, with an average 14 years of age. They composed two groups: low blood lead level (less than 5µg/dl) and high blood lead level (greater than 10µg/dl). Four years ago, participants had been assessed for social skills and behavior problems (IHSA-Del-Prette, SSRS-BR), through the WISC-III and TDE. As a result, the group with high blood lead levels presented greater IQ impairment and more behavior problems. No differences in academic performance and social skills (as evaluated by the teacher) were evidenced, but the high blood lead group assessed themselves as having a better social skills repertoire. Possible explanations and implications for these results are discussed and new questions for research are presented.

Keywords: Academic performance, Intellectual performance, Social skills, Blood lead level, Behavior problems.

Desempenho intelectual e acadêmico de adolescentes contaminados por chumbo: relação com as habilidades sociais

Resumo

Este estudo investigou o impacto da plumbemia, quatro anos após a intoxicação, sobre o desempenho intelectual (QI) e acadêmico e, oito anos após sobre problemas de comportamento e habilidades sociais. Participaram 54 adolescentes, com idade média de 14 anos, divididos em dois grupos: com

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baixa plumbemia (inferior a 5µg/dl) e com alta plumbemia (superior a 10µg/dl). Os participantes avaliados em medidas de habilidades sociais e problemas de comportamento (IHSA-Del-Prette, SSRS-BR), haviam sido avaliados, há quatro anos, com o WISC-III e o TDE. Os resultados apontaram prejuízos para o grupo com alta plumbemia no QI de Execução e em indicadores de problemas de comportamento. Não foram observadas diferenças entre os grupos quanto ao desempenho escolar e às habilidades sociais avaliadas pelo professor, porém o grupo com alta plumbemia se autoavaliou com melhor repertório de habilidades sociais. São discutidas possíveis explicações e implicações para esses resultados e novas questões de pesquisa são apresentadas.

Palavras-chave: Desempenho acadêmico, Desempenho intelectual, Habilidades sociais, Nível de chumbo no sangue, Problema comportamental.

El rendimiento intelectual y académico de los adolescentes contaminados por plomo: su relación con las habilidades sociales

Resumen

Este estudio investigó el impacto que el plomo tiene sobre el rendimiento intelectual (CI) y el rendimiento académico cuatro años después que la sangre del individuo fue contaminada por el plomo, así como problemas de conducta y habilidades sociales ocho años después de la intoxicación. 54 adolescentes, con una edad promedio de 14 años, participaron del estudio. Fueron formados dos grupos: uno con bajo nivel de plomo en la sangre (menos de 5µg/dl) y otro con nivel elevado de plomo en la sangre (más de 10µg/dl). Cuatro años antes, los participantes habían sido evaluados en cuanto a habilidades sociales y problemas de comportamiento (IHSA-Del-Prette, SSRS-BR) por el WISC-III y TDE. Como resultado, el grupo con altos niveles de plomo en la sangre presentó un mayor daño en su CI y problemas de comportamiento mucho más numerosos. No se observaron diferencias en su rendimiento académico y ni en las habilidades sociales (según evaluación hecha por profesor), pero el grupo con el alto nivel de plomo en la sangre se autoevaluó como teniendo un mejor repertorio de habilidades sociales. Se discuten posibles explicaciones y las implicaciones para esos resultados y se presentan nuevas preguntas de investigación.

Palabras clave: Rendimiento académico, Rendimiento intelectual, Habilidades sociales, Nivel de plomo en la sangre, Problemas de conducta.

Issues related to intellectual and academic performance and interpersonal relations among children and adolescents are foci of research interest due to their impact on academic achievement, socioemotional development and other indicators of a child's psychosocial adjustment (Bandeira, Rocha, Souza, Del Prette & Del Prette, 2006; Caprara, Barbaranelli, Pastorelli, Bandura, & Zimbardo, 2000). It is widely acknowledged that risk factors negatively affect these child development indicators, while different protective factors exert positive influence (Bandeira, Koller, Hutz & Foster, 1996; DiPerna, 2006; Feitosa, 2007). Among risk factors that remain unexplored in Brazilian research literature, Dascanio, Valle and Rodrigues (2010) highlight toxic

environmental conditions, including lead contamination, which is the focus of this study.

The highest level of lead a child tolerates, according to international regulatory agencies like the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC) and the American Conference of Governmental Industrial Hygienists (ACGIH) is 10µg/dl in the blood. Extensive literature on this issue (Chiodo, Jacobson & Jacobson, 2004; Kordas et al., 2006; Lanphear et al., 2005; Vega et al., 2005) has shown that lead intoxication with levels that surpass 10µg/dl in the blood stream may cause neurobehavioral alterations, headaches, visual impairment, changes in speech, deficits in psychological development, harming intellectual and

academic development and specific behaviors, including hyperactivity.

Studies on lead poisoning show that there are distinct impacts when exposure takes place during the prenatal period or in early childhood, with greater impact during the gestational period, especially for boys (Figueiredo, Capitani, & Gitahy, 2005; Kahn, Kelly, & Walker, 1995). For infants, the harm may be partially reversible (Tong, Baghurst, Sawyer, Burns, & McMichael, 1998; Dietrich, Berger, Succop, Hammond, & Bornschein, 1993).

In addition, some studies present results that clearly show that lead poisoning causes permanent damage, affecting both intellectual and academic development, especially in children (Ostenberg, Borjesson, Gerhardsson, Schutz, & Skerfving, 1997; Schwartz, 2004; Plusquellec et al., 2010). These results are compatible with results from a Brazilian study by Bechara (2004), who also concluded that lead poisoning can cause irreversible damage to the child's nervous system, affecting attention, memory, intelligence and social behaviors (greater hostility).

A measure of intellectual performance, used in several studies, is the Intellectual Quotient (IQ). A meta-analysis by Needleman and Gatsonis (1990) indicated that each 1µg/dl increase in the blood lead level reduces the IQ by 0.24 points. Stiles and Bellinger (1993) confirmed this data with respect to vocabulary and comprehension. Other studies (ATSDR, 1994; Dascanio, Valle & Rodrigues, 2010; Wasserman et al., 1997) also show a negative impact on sensory motor skills, measured by the WISC-III performance scale.

Since the 1980's, various studies have also focused on the impact of the blood lead level (BLL) on socioemotional development. Yule et al. (1981) found correlations between blood lead level, intelligence and behavioral changes (aggressiveness), which were later confirmed by other studies (Bellinger, 1995; Olympio, Gonçalves, Gunther & Bechara, 2009; Tong, McMichael & Baghurst, 2000).

Data available in literature indicates that, in addition to immediate impacts, intoxication by lead may present consequences and aftereffects in later stages of development. Some studies have indicated a relationship between lead levels in childhood and a life of crime in later life: teen years (Needleman, Riess, Tobin, Biesecker & Greenhouse, 1996; Nevin, 2007). In this case, research carried out

by Nevin (2007) should be mentioned, in which forensic data was collected, demonstrating a strong correlation between high blood lead levels in pre-school children and criminality. Whilst analyzing international trends related to crime rates since 1940, this author suggested, based on a multiple regression analysis, a strong correlation between critical periods of high levels of exposure to lead (paint in old houses and gasoline) and higher rates of criminality. The author observed an inverse tendency in periods that followed social measures to remove lead from gasoline and from the environment. Specifically, studies that explore the correlation between exposure to lead and criminality suggest a cyclical process in which exposure may lead to a lack of success in academic realms, and this in turn increases the risk of involvement in crimes (Mendelsohn, et al., 1998; Needleman et al., 1996; Nevin, 2007).

Although such studies associate lead poisoning with antisocial behavior, it is not clear if the aforementioned behavior is caused directly by possible brain damage, or if it is a side effect of cognitive impairment (Lidsky & Schneider, 2006; Needleman, McFarland, Ness, Fienberg & Tobin, 2003). The relationship between these variables is intricate, since children with brain damage caused by lead poisoning manifest cognitive disabilities that are usually associated with academic difficulties and their psychological repercussions (for example, loss of self-confidence and low self-esteem and impairment of the relationship with peers (D'Avila-Bacarji, Marturano, Elias, & Santos, 2005; Gardinal-Pizato, 2010; Marturano, Trivellato-Ferreira, & Gardinal, 2009; Polleto & Koller, 2008).

This brief review shows that BLL may affect the quality of interactions with others, socioemotional development and adaptive functioning. Such an impact may occur immediately, when it comes to intellectual performance, or also in the long run, with implications for social behavior, which would include both positive indicators (for example, social skills repertoire) and negative (for example, behavior problems). Thus, regardless of the triggering factors, the impact of BLL could manifest itself in association with social skills and social competence deficits, which in turn present a negative correlation with behavior problems (Z. A. P. Del Prette & Del Prette, 2005; Feitosa, 2007). Although the

literature in this field does not use the terms social skills and social competence, data that associates lead levels with deficits in children's and adolescent's social repertoire are presented in most case studies, as shown in the meta-analysis by Marcus, Fulton and Clarke (2010).

A. Del Prette and Del Prette (2001) define social skills (SS) as a set of behavioral classes and subclasses an individual learns in order to react to various interpersonal demands. According to Del Prette and Del Prette (2001), social competence refers to the capacity people have to organize thoughts, feelings and behaviors in a way that attends to the demands that exist in their social environment, assuming some evaluation criteria, such as: "achievement of objectives, maintenance or improvement of self-esteem and relationship quality, balance between gains and losses among the partners in interaction, respect and the application of human rights" (p.34). These criteria, which the authors emphasize, include immediate (instrumental to the individual) as well as medium and long term results (important for the interlocutors and social group), characterizing the instrumental and ethical-moral dimensions of social competence (Z. A. P. Del Prette & Del Prette, 2010).

When environmental conditions are favorable, social skills co-occur with a broad set of adaptive behaviors, such as: good academic performance, coping strategies in situations of stress or frustration, self-care (hygiene, health and safety), independence while performing tasks (at school, at home and among groups of friends) and cooperation (Bandeira et al., 2006; Caldarella & Merrel, 1997; Caballo, 2003; Z. A. P. Del Prette & Del Prette, 2005). On the other hand, there is mounting evidence that social skills deficits are related to weak academic performance, delinquency, drug abuse, marital crises, negative educational practices and varied emotional disorders, such as anxiety disorders, depression and social phobia (Z. A. P. Del Prette & Del Prette, 2002; Elliott & Gresham, 2008; Gresham, 2004). Some longitudinal studies indicate that a good social skills repertoire during childhood can be a predictive variable of a positive developmental trajectory in infancy (Caprara et al., 2000; Malecki & Elliott, 2002; Walker & Severson, 2002).

In a review about the correlation between learning disabilities and social skills deficits, carried out in the 1990's, Gresham (1992)

proposed three hypotheses that are commonly assumed in studies related to this area. One of them is the causal hypothesis, in which social skills deficits in children with learning disabilities would be caused by dysfunctions in the central nervous system. Another is the hypothesis of concomitance, in which the social skills deficits would coexist with and result from academic difficulties. The third is the correlational hypothesis, in which social and academic skills would simply be correlated, with no cause-and-effect relation. Another possible explanation for the association between social skills and academic performance is the possible functioning relation between these two variables. In support of this hypothesis, Molina and Del Prette (2006) found that an academic intervention generated improvements in reading and writing, while an intervention in social skills generated an improvement in the social skills as well as in the academic performance of the children. In another study, Feitosa (2007) found that the relation between social skills and academic performance was measured by cognitive competence, producing evidence of the direct and indirect influence social skills have on intellectual capacity and academic competence. This hypothesis is substantiated by regression studies that specify relevant skills associated with good academic performance, such as cooperation and sociability (Del Prette, Del Prette, Oliveira, Gresham & Vance, 2012), and by other studies as academic enablers (Caprara et al., 2000), with some classes especially referred to as academic social skills (Z. A. P. Del Prette & Del Prette, 2005).

This study recognizes that damage caused by BLL may generate medium and long-term impacts that lead to child development difficulties while altering several cognitive performance measures, associated to behavior problems. Considering that, since social skills are substitutes for behavior problems, on the other hand, the social skills repertoire of the population poisoned by lead should be assessed and compared, in similar social conditions, to that of individuals who were not poisoned. The unexplored possibility of simultaneously evaluating medium-term data (four years after contamination) and long-term data (eight years after contamination) was considered. Using an *ex post facto* design with a comparison group, this study aims to evaluate the relations between BLL and indicators of intellectual

competence (IQ) and academic (reading, writing and arithmetic performance), four year after the contamination and, in addition, the impact of these variables on the social repertoire eight years after the contamination.

Method

This study received approval from the Research Ethics Committee at UNESP–Bauru (Process No. 2651/46/01/09, approved 12/18/2009) and met all of the requirements of Resolution No. 196, issued on October 10, 1996, which regulates research involving human beings.

Participants

Participants were 54 adolescents, aged 13 to 17 ($M=14$ years old; $SD=2.19$), with high or low blood lead levels, residents in a neighborhood contaminated by lead due to exposure to toxic residues through the smokestacks of a battery factory, in an interior city in São Paulo State with approximately 340,000 inhabitants, in 2002. Healthcare professionals evaluated all adolescents through laboratory tests provided for by the Adolfo Lutz Institute (São Paulo/Brazil)¹. The researchers of the Study and Research Group on Lead poisoning in Children from Bauru (GEPICC) systematically evaluated and frequently monitored the population intoxicated by lead between 2002 and 2006. The study participants were distributed into two groups, considering the level of BLL:

High BLL Group (HBG). Composed of 27 adolescents with a BLL higher than $10\mu\text{g}/\text{dl}$, located through the registration of children (now adolescents) who, in 2006², still showed lead contamination above tolerable standards and had their intellectual capacity measured with the help of the WISC-III, while the academic achievement was measured using the

TDE³. These adolescents were distributed across various different elementary and junior high school grades (1st and 3rd= 3.7%; 5th= 7.4%; 6th=3.7%; 7th and 8th =18.5%) and high school (9th=22.2%; 10th and 11th=11.1%) and predominately displayed low socioeconomic levels (B2=11%; C=74% e D= 15%), according to the Brazilian Standards (*Critério Brasil*)⁴. This sample was selected from the identified population of 324 children, aged 0 to 12 years old, indicated by the Regional Board of Health (DIR X) and seen at the Applied Psychology Centre – CPA of the Paulista State University between 2002 and 2006, in the emergency care project for children from 0 to 12 years old poisoned by lead.

Low BLL Group (LBG), also composed of 27 participants with lead contamination below $5\mu\text{g}/\text{dl}$, distributed throughout various different elementary and junior high grades (5th= 3.7%; 6th= 7.4% and 7th and 8th=26%) and high school (1st=26% and 2nd= 11%) and at a low socioeconomic level (B2= 3.7%; C= 89% and D= 7.3%). This sample was extracted from a population of 539 individuals, indicated by the DIR X as presenting lead contamination below $5\mu\text{g}/\text{dl}$, the method's qualifying limit. Table 1 presents information concerning sex, age, grade and socioeconomic level of the participants of each one of the groups.

Instruments

Social Skills Rating System (SSRS-BR). This inventory is used to evaluate social skills, problematic behaviors and academic competence. It was originally published by Gresham and Elliott (1990) and validated to Portuguese with satisfactory internal consistency and test-retest temporal stability coefficients (Bandeira, Del Prette, Del Prette & Magalhães, 2009). The frequency (Never, Sometimes, Always) at which the child

¹ The BLL diagnosis was reached in 2002, using *furnace-Zeeman* atomic absorption spectrophotometry with the SIMAA 6000 Perkin Elmer model, which could only quantify concentrations starting at $5\mu\text{g}/\text{dL}$ (Padula, 2006).

² The most recent BLL evaluation of this community was carried out in 2006, associated with the evaluation of intellectual and academic competences.

³ The WISC-III and TDE were applied in 2006 at the Applied Psychology Centre of a public university in upstate São Paulo/Brazil.

⁴ According to the Brazilian Economic Standards Questionnaire (Critério Brasil, IBOPE/ABEP, 2008, <http://www.abep.org>), which evaluates purchasing power based on the ownership of durable consumer goods, education level of the household head and other factors, dividing the Brazilian population of 2007 into five classes, in decreasing order: A1 (0.9%), A2 (4.1%), B1 (8.9%), B2 (15.7%), C1 (20.7%), C2 (21.8%), D (25.4%) and E (2.7%).

Table 1 – Socio-demographic information about participants in the groups with high and low blood lead level (BLL).

Groups	Boys AF(RF)	Girls AF(RF)	Age Mean (sd)	Grade Mean (sd)	NSE Mean (sd)
LBG – Low BLL	15(56)	12(44)	14.9(1.42)	8.70(2.63)	5.04(0.33)
HBG – High BLL	12(44)	15(56)	15.52(1.57)	8.74(3.18)	5.04(0.51)

Note: AF = Absolute Frequency; RF = Relative Frequency (%); sd = standard deviation.

displayed the skills described in the instrument is evaluated. Item scores are summed up, producing a total score referred to in percentiles. In the present study, only information about the total social skills and behavior problems scores⁵ were used, which teachers obtained in their evaluations, were used.

Inventory of Social Skills for Adolescents (IHSA-Del-Prette, by A. Del Prette, & Del Prette, 2009). Self-reporting instrument to assess social skills, constituted by 38 items, which contemplate the main demands on adolescents between ages 12 and 17, in terms of interpersonal performance among different interlocutors and contexts. For each of the items, the adolescent is expected to estimate (a) how difficult it is to present the reaction indicated in the item; (b) how frequently the reaction indicated in each item is presented. In these two indicators (frequency and difficulty), the answers are measured on a five-point Likert scale. For this study, only the general score for social skills was considered.

School Performance Test (SPT, by Stein, 1994). The SPT is a psychometric instrument that seeks to objectively evaluate the school performance of elementary students, from the 1st to the 6th grade, while writing, doing arithmetic and reading, and has been validated in Brazil based on a sample from Porto Alegre (RS). The test presents results in raw scores, through a count of correct answers. As indicators of reliability, the Alpha's coefficients referred to in the TDE are as follows: Writing=0.95, Arithmetic=0.93, Reading=0.99 and Total=0.99.

⁵ Considering the high correlations between the social skills subscales and externalizing and internalizing behavioral issue scales, evaluated by the teacher, the researchers decided to use a global score for each of the subscales to represent the psychological construct concerned.

Wechsler Intelligence Scale (WISC-III, by Wechsler, 1997). An adapted version was used by Figueiredo (2002) in the Brazilian population to evaluate children's intellectual performance. The instrument is composed of a verbal scale (VIQ), an execution scale (EIQ) and a total scale (TIQ). The verbal scale contains six subtests (Information, Similarities, Arithmetic, Vocabulary, Comprehension and Digit Span), while the execution scale contains seven subtests (Picture Completion, Picture Arrangement, Coding, Block Design, Object Assembly, Symbol Search and Maze), and the total scale represents the sum of these two scales.

Data collection procedure

Following the documentary survey of the records of all children evaluated by the Applied Psychology Centre between 2002 and 2006, the data was organized in a spreadsheet, containing information concerning sex, BLL and intelligence scores, academic performance. Information was complete for 54 children. Next, the IHSA-Del-Prette was applied in a classroom the board of the institution provided. The teacher answered the SSRS-BR at school. Although the SSRS-BR is used to investigate the children's characteristics, in this study, it was decided that it would be used to investigate these characteristics in adolescents⁶ as well, due to the lack of an instrument that was specifically designed for this age group.

Data analysis procedure

The data was entered into the *PASW-18* software for Windows. On a preliminary basis, each group proceeded through a univariate (*Z-scores* greater than roughly 3.29 standard

⁶ In Brazil, there is no normative data for the adolescent population in the SSRS-BR, but the original American version of this scale is aimed at children and adolescents.

deviations) and multivariate outliers analysis (Mahalanobis distance test with $p < .001$, according to Uriel & Aldás, 2005). For the groups' sociodemographic equivalency analysis, three different tests were employed for gender (*Chi-squared*), age (*Student's t test* for independent samples) and education level and socioeconomic level (*Mann Whitney U test*).

In a second phase, the differences between the indicators of intellectual and academic performance, social skills and behavior problems were evaluated, comparing the groups with high and low BLL. Taking into account the number of dependent variables, Multivariate Analysis of Variance (MANOVA) was used, which permits keeping the level of Error Type 1 constant, when one works with multiple dependent variables. An exploratory analysis of data was conducted, in order to verify the assumptions of normality, homogeneity of univariate and multivariate variance and sphericity. Univariate normality (*Kolmogorov-Smirnov test*) was confirmed, but with significant results shown for certain variables; homogeneity (*Levene's contrast*) was not significant, and the same occurred with multivariate homoscedasticity (*M of Box = 44.98, F=1.04; p= 0.39*). The correlation between dependent variables (*Bartlett's sphericity contrast*) was significant ($p < 0.001$), justifying the use of MANOVA.

Although some of the dependent variables did not adhere to the criteria of normality of distribution, possibly due to the sample size, given that there was compliance with the remaining assumptions, it was decided to make use of MANOVA. Furthermore, outliers were not found and certain authors (Wilcox, 1995, Tabachnik & Fidell, 2001) argue that the strength of the test is not significantly affected by the normality violation when groups are similar in size and the number of dependent variables is less than the number of cases in each cell. Finally, the degrees of freedom (df) for the standard deviation were higher than the minimum recommended (df= 20).

Considering the sample characteristics, the most conservative of measures was resorted to (Pillai's criteria) for the main effects and for the coefficient η^2 as a measure of effect size. Taking into account that the use of multiple MANOVA as *post hoc* analyses may inflate Error Type 1 when there is a correlation between the dependent variables, the Roy-

Bargmann Stepdown Analysis (Block, 1966; Block & Haggard, 1968; in Tabachnik & Fidell, 2001) was employed as a *post hoc* test. This method is very sensitive to analyze the individual effects on dependent variables, controlling for the effects of mutual correlation. It also allows one to analyze the relative importance of each dependent variable in terms of the effect of the independent variable. Since this analysis implies defining the priority with which the dependent variables are entered into the equation, the following order was adopted in this study: social skills (evaluated by the teacher), social skills (self-evaluation), Execution IQ, Verbal IQ, behavior problems, academic performance in arithmetic, in reading and in writing. The priorities were determined according to the studies found in the literature, which show the predominance of research on social skills evaluated by teachers and of the IQ as being potentially impaired by BLL.

Results

The following are the descriptive and inferential analysis results of equivalence between groups and the indicators of *intellectual performance (IQ)*, *academic performance*, *behavior problems and social skills*.

According to the data presented in Table 1, in the Methods section, groups HBG and LBG were equivalent according to gender ($\chi^2 = 0.667$, $p = 0.41$), age ($t = 1.54$, $p = 0.13$), school grade ($U = 345.50$, $p = 0.73$) and socioeconomic level ($U = 363.50$, $p = 0.98$), which indicates similarity between the groups that were studied.

As show in Table 2, the differences in intellectual performance, academic performance, social skills and behavior problems were significant, according Pillai's criteria ($F = 3.59$, $p \leq 0.01$, high potency was observed = 0.98, and so was an equally large effect $\eta^2 = 0.41$). As for intellectual performance, it was found that the average of both groups was lower than that which was expected for their age, 100 points, regardless of the BLL. Still, a marginally significant difference was observed between the groups in Verbal IQ ($F = 3.67$, $p = 0.06$) and a highly significant difference in Execution IQ ($F = 6.06$, $p = 0.01$), both in favor of the group with a low BLL. As for academic performance, there were no differences in the writing, arithmetic and reading subscales. All of them were situated in

Table 2 – Descriptive data about intellectual performance, academic performance, social skills and behavior problems, for the groups with low and high blood lead level.

Variables	LBG M(sd)	HBG M(sd)	StepDown F	p
Social Skills (teacher)	36.52(10.96)	32.04(10.88)	2.271	.13
Social Skills (self-report)	86.11(34.40)	102.89(21.62)	8.270	.00*
Verbal IQ	63.07(32.53)	74.44(28.54)	3.677	.06
Execution IQ	61.93(27.82)	61.07(25.19)	6.069	.01*
Behavior Problems	7.04(6.59)	11.56(4.94)	4.241	.04*
Arithmetics	13.52(7.84)	8.00(6.24)	1.772	.19
Writing	18.81(12.03)	11.70(10.97)	.135	.71
Reading	52.07(25.29)	33.19(28.96)	1.100	.30

Note: * = $p < 0.05$.

average or below average ratings in all of the subtests analyzed (Reading, Writing and Arithmetic).

Regarding social skills, based on the teacher's assessment, no differences were found between both groups. However, in self-evaluation ($F = 8.27$, $p < 0.01$), the adolescents with high BLLs reported a greater repertoire of social skills when compared to the group with low BLLs. Both groups also differed in behavior problems ($F = 4.24$, $p = 0.04$), with higher scores coming from the group with high BLLs.

Discussion

In accordance with other research results (Needleman & Gatosis, 1990; Needleman, 2004; Tong, McMichael & Baghurst, 2000), the present study also found a difference in intellectual performance on the execution scale for adolescents intoxicated by lead, and a marginally significant difference in the verbal scale. This result is also consonant with the aforementioned studies, highlighting that verbal IQ deficits are associated with verbal and linguistic capacity, as well as with familiarity with culture, requiring skills and knowledge acquired in school and at home. In this respect, both adolescents with low and high BLL presented similar characteristics when it came to educational and socioeconomic background. On the other hand, some authors go as far as to associate Execution IQ as being more vulnerable to the neurotoxic effects of lead (Hanninen et al., 1998; Schwartz, 1994).

What was unexpected was that no difference in the data was found concerning academic performance between the groups. However, it is worth considering that the IQ score, referred to in literature as the predicting

variable of academic performance, remained below expected averages for both groups, and the same was true for academic performance results. It is also possible that the lack of differences between the groups results from the quality of education these children received, more than the initial differences in intelligence. The results of the studies conducted by Banks, Ferretti and Shuccard (1997), Moreira and Moreira (2004) and Bellinger (1995), although these did not directly evaluate academic performance, suggest that the decrease in intelligence (which directly influences school performance) is one of the probable effects of lead. In general, these results highlight the multi-determination of behavior and the difficulty researchers face to establish causal hypotheses. As emphasized, in addition to the IQ, socioeconomic level and social skills have also been recognized as predictors of academic performance (Gardinal-Pizato, 2010), suggesting that social skills (not deficient in this study) may have functioned as a protective factor, reducing loss in academic performance.

Some authors (Ernhart & Greene, 1990; Hebben, 2001; Kaufman, 2001) indicate that causality between lead and intellectual performance is not fully demonstrated and that other risk factors, such as sociodemographic conditions, level of education of the parents, history of medical problems, among others, can compromise reliability and validity in this causal relationship. In the present study, both groups' scores were below the average range (90-110), suggesting that other variables, like sociodemographic factors for example, could constitute risk factors that mitigate the possible impact of the BLL.

It is important to remember, as several researchers alert (Canfield et al., 2003; Lanphear et al., 2005; Marturano & Elias,

2009), that even levels below 10 μ g/dl may cause damages to a child's development. From this point of view, one may consider that all participants in the present study were somehow exposed to lead, even with a BLL below the qualifying limits (5 μ g/dl) and that, therefore, they could also present some form of intellectual commitment. Future studies comparing children with BLL and samples with no history of exposure to lead may permit an even more precise evaluation of the compromises caused by BLL. In this sense, this study does not solve the uncertainty surrounding the impact of BLL on intellectual performance. On the other hand, it suggests that lead poisoning represents a risk factor that adds to other variables, such as poverty and poor environmental quality, enhancing child development impairments.

As for social skills, significant differences between the teachers' evaluations were not observed and the difference found through the adolescents' self-assessment was favorable to the group with BLL. This result differs from some other studies (Bellinger, 1995; Needleman et al., 2003; Tong et al., 2000) that reported impairment in social skills (when evaluated by parents and teachers) of children and adolescents intoxicated by lead; however, none of these studies evaluated social skills in a systematic fashion. The focus was on problems related to conduct (Bellinger, 1995; Needleman et al., 2003; Olympio et al., 2009; Tong et al., 2000), which, in this study, also distinguished the adolescents with high BLLs from those with low BLLs, suggesting that the acknowledged multiplicity of these problems might include some effects related to lead on the central nervous system, with a medium or long-term impact.

Data more related to behavior problems concerning repertoire would entail an expectation of social skill deficits, in accordance with extensive literature on competing relationship between these variables (Z. A. P. Del Prette & Del Prette, 2005; Gresham, 2009). Admittedly, the better social skills repertoire identified only through self-evaluations (but not through the teachers' evaluation) can be understood as incidental data, demanding further exploration in future studies. Also, one may assume that the behavior problems are a side effect of more permissive and overbearing educational

contingencies alongside these children, now adolescents. This hypothesis finds some support in data presented by Dascanio and Valle (2007), whose results showed that the mothers of children with high BLL employed more relaxed disciplinary educational practices than the mothers of the (then) children with low BLL.

Another hypothesis for the difference in the self-assessed social skills of adolescents with BLL is that they may have received greater stimulation by health departments in terms of care and monitoring and special attention in periodic multidisciplinary assessments. This condition may have resulted in demands for social performance among different social circles, whereupon they were required to answer questions about how they felt, self-assess general conditions of psychological functioning, describe routines etc. (Rodrigues, 2002; Dascanio & Valle, 2008), which could have served as an indirect training for social behaviors. Such monitoring may also have influenced their parents and teachers, providing greater stimulation and care for these children, with a possible impact on the self-esteem of these adolescents. Considering that this superiority was not confirmed in the teachers' assessments and that these assessments indicated that there were more behavior problems in the group with high BLL, however, the data suggest a greater effect of self-esteem and self-efficacy, which has been vastly correlated with a positive evaluation of social skills (Pajares & Olaz, 2008).

A third hypothesis, the higher scores related to behavior problems among the adolescents with high BLLs, pointed out by the teachers, lead to evidence that children with behavior problems, especially externalizing, tend to self-assess more positively than external evaluators, possibly due to discriminatory flaws reminiscent of their own social repertoire (Gresham, 2009). From this perspective, the high ratings for social skills can be understood as associated to unrealistic perceptions of their own repertoire, which could be the focus of a more detailed investigation.

Concluding remarks

The present study joins data produced through a multimodal assessment with different measuring instruments and informants, concerning the repertoire of social skills,

intellectual and academic performance and behavior problems of adolescents with high and low BLLs. The results point to negative medium-term effects caused by BLL (especially on the intelligence and execution IQ scores) as well as to long term effects also caused by BLL (especially to the indicators of behavioral issues), both consistent with the literature in the field. Some data divergent from what is found in specialized literature was obtained, and some different explanatory hypotheses were presented for future investigations.

In spite of the significant results produced, some study limitations are acknowledged. One of these limitations concerns the small size of the samples and the absence of a systematic longitudinal follow-up for variables studied herein. The issue of methodological diversity employed in the reference studies should also be taken into account, with different measuring instruments, restraining certain comparisons. For example, the WISC is a scale that is widely used in different studies; on the other hand, the TDE, the SSRS-BR and the IHSA-Del-Prette were not used in previous studies with individuals with BLL, which restricts the scope of the current comparative results, especially related to the social skills repertoire used in this study for comparison, a sample in similar social conditions. There is also the question of the variety of informants when it comes to social repertoire, since literature takes into account, in most cases, teachers and parents, instead of the children themselves, limiting possible comparisons with the present study.

The research design, with the use of a comparison group and a multimodal evaluation of the adolescents' social and academic repertoire, as well as the control of sociodemographic variables, as suggested by Kaufman (2001), can be considered a methodological breakthrough when compared to currently available literature. It also stands out as well for reiterating the importance of governmental actions that focus not only on physical health promotion policies, but on policies that stimulate the psyche and acknowledge other conditions, which could also mitigate the environmental impact such incidents have on the development of children and adolescents.

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