J. Child Psychol. Psychiat. Vol. 41, No. 3, pp. 291–299, 2000
Cambridge University Press

0021–9630/00 $15.00 + 0.00

School and Neuropsychological Performance of Evacuated Children in Kyiv 11 Years after the Chornobyl Disaster

Leighann Litcher, Evelyn J. Bromet, Gabrielle Carlson, Nancy Squires, and Dmitry Goldgaber
State University of New York at Stony Brook, U.S.A.

Natalia Panina and Evgenii Golovakha
Ukrainian Academy of Sciences, Kyiv, Ukraine

Semyon Gluzman
Ukrainian Psychiatric Association, Kyiv, Ukraine

This paper examines the cognitive and neuropsychological functioning of children who were *in utero* to age 15 months at the time of the Chornobyl disaster and were evacuated to Kyiv from the 30-kilometer zone surrounding the plant. Specifically, we compared 300 evacuee children at ages 10–12 with 300 non-evacuee Kyiv classmates on objective and subjective measures of attention, memory, and school performance. The evacuee children were not significantly different from their classmates on the objective measures (grades; Symbolic Relations subtest of the Detroit Test; forms 1 and 2 of the Visual Search and Attention Test; Benton Form A; Trails A; Underline the Words Test) or on most of the subjective measures (the attention subscale of the Child Behavior Checklist completed by mothers; the attention items of the Iowa Conners Teacher's Rating Scale; mother and child perceptions of school performance). The one exception was that 31.3% of evacuee mothers compared to 7.4% of classmate mothers indicated that their child had a memory problem. However, this subjective measure of memory problems was not significantly related to neuropsychological or school performance. No significant differences were found in comparisons of evacuees and classmates who were *in utero* at the time of the explosion, children from Pripyat vs. other villages in the 30-kilometer zone, and children manifesting greater generalized anxiety. For both groups, children with greater Chornobyl-focused anxiety performed significantly worse than children with less Chornobyl-focused anxiety on measures of attention. The results thus fail to confirm two previous reports that relatively more children from areas contaminated by radiation had cognitive deficits compared to controls. Possible reasons for the differences in findings among the studies are discussed.

Keywords: Children, disaster, epidemiology, neuropsychology, school performance.

Abbreviations: CBCL: Child Behavior Checklist; CMAS: Children's Manifest Anxiety Scale; GPA: grade point average; VSAT: Visual Search and Attention Test.

Introduction

The Chornobyl nuclear power plant accident of 1986 was the worst recorded nuclear power plant accident in history. The violent explosion of reactor four and the resulting graphite fire exposed approximately 4,000,000 people to levels of radiation 5 times greater than any fallout from nuclear weapons tests (Goldman, 1997; Shcherbak, 1996). Approximately 200,000 people were evacuated from areas surrounding Chornobyl (Goldman, 1997). The unprecedented nature of the accident and the sociopolitical changes that occurred since that time have presented methodological challenges for determining the immediate and long-term psychosocial consequences (Bromet, 1995). Although there have been a number of recent studies of the psychological impact on adults (cf. Havenaar & van den Brink, 1997), few studies have focused on children. However, young children were found to have the greatest risk of thyroid cancer (Bard, Verger, & Hubert, 1997) and, as a result, the wellbeing of exposed children remains a major public concern in Ukraine and in other parts of the former Soviet Union.

Prior research on children exposed to other natural or technological disasters suggests that the ensuing stress can lead to increases in behavioral problems, internalizing symptoms, and post-traumatic stress symptoms (Aptekar & Boore, 1990; Bromet & Dew, 1995; Vogel & Vernberg, 1993; Yule, Udwin, & Murdoch, 1990). For example,

Requests for reprints to: Dr E. Bromet, Department of Psychiatry and Behavioral Science, State University of New York at Stony Brook, Putnam Hall-South Campus, Stony Brook, NY 11794-8790, U.S.A.
(E-mail: Ebromet@mail.psychiatry.sunysb.edu).

Since this study is a collaborative project with investigators in Ukraine, the paper follows the original Ukrainian spellings for Chornobyl (Chernobyl) and Kyiv (Kiev).

Breton, Valla, and Lambert (1993) examined the mental health of 87 3–11-year-olds exposed to a PCB fire in Montreal and 87 unexposed controls. One year after the fire occurred, exposed children aged 6–11 displayed significantly more post-traumatic stress symptoms than controls but were otherwise similar (Breton et al., 1993). Yule and colleagues (1990) reported that girls who survived the sinking of a cruise ship developed specific fears related to the trauma. Of direct relevance to the current study, Bromet, Hough, and Connell (1984) assessed the mental health of 11-year-old children 3.5 years after the Three Mile Island nuclear power plant accident using the Achenbach Child Behavior Checklist (CBCL; administered to the mothers), and child self-reports of fearfulness and self-esteem. Four groups were assessed: children living within 10 miles of the site, children whose fathers worked at Three Mile Island, children living within 10 miles of a comparison nuclear plant, and children whose fathers worked at the comparison plant. They found no statistically significant group differences in the children's mental health (Bromet et al., 1984).

Two recent studies of the accident at Chornobyl reported that compared to controls, children exposed *in utero* were more likely to display borderline intelligence (Kolominsky, Igumnov, & Drozdovitch, 1999) and mental retardation (Nyagu, Loganovsky, & Loganovskaja, 1998) at age 7. However, Kolominsky and colleagues did not find a significant dose-response relationship between their estimated radiation exposure level and intelligence and attributed the higher rate of borderline intelligence to socioenvironmental and "stressogenic" factors. On the other hand, Nyagu et al. reported significant dose-response effects in a subsample of 50 exposed *in utero* children, although the method for determining radiation exposure dose, using retrospective reconstruction, was not clearly delineated.

In general, studies of the effects of disasters on children report inconsistent results due in part to differences in the level of trauma associated with the events, the age distribution of the samples, the timing of the data collection, and assessment procedures (Saylor, 1993; Vogel & Vernberg, 1993). In addition, many studies have relied on samples of convenience. It is also noteworthy that few studies have used objective measures of performance even though these measures eliminate recall bias and provide an important behavioral indicator of the consequences of severe stress (Saigh, Mroueh, & Bremner, 1997).

The current study examines the possible impact of long-term stress from radiation exposure on cognitive functioning in 300 children from families evacuated to Kyiv. The children were assessed 11 years after the Chornobyl accident when they were 10–12 years old and were compared to a classmate comparison group. The impetus for this examination was the concern expressed by mothers and teachers that evacuee children had problems with their memory, had difficulty concentrating in school, and performed more poorly than other children. Thus, our study addressed whether, in a representative sample, systematic differences existed in actual or perceived school or neuropsychological performance. Cognitive performance was evaluated in four ways. Objective measures of nonverbal intelligence, memory, and attention were obtained. In addition, school performance was examined using both grade level performance and teacher ratings of attention. Parent ratings of children's attention were also measured using a standardized rating scale. Finally, the perceptions of school grades by mothers and children were assessed.

In addition, we sought to determine whether specific stress or exposure variables increased the risk of attention, memory, or school performance problems. To assess stress, we stratified children based on their levels of generalized anxiety and on a measure of Chornobyl-focused anxiety. In the absence of radiation exposure estimates, we compared evacuee and classmate children who were *in utero* at the time of the explosion, and also compared evacuee children from Pripyat versus other villages in the 30-kilometer evacuation zone.

Methods

Design and Sample

The design involved an assessment of evacuee children who were *in utero* and aged up to 15 months (born between January 1985 and January 1987) at the time of the explosion (26 April 1986). This age group was regarded as a high-risk group because the excess risk for thyroid cancer (Bard et al., 1997) has resulted in widespread hypervigilance by mothers, teachers, and the medical community about their health and wellbeing. It is commonly believed that these children had special problems in school and were distinguishable from their classmates in terms of performance and absenteeism.

When the fieldwork for the present study began, no single complete list of families evacuated to Kyiv after the Chornobyl accident existed. In order to assemble a sampling frame of evacuee families with children in the target age range, three large lists were integrated: the National Register of Persons Affected by Radiation as a Result of the Chornobyl Accident (founded by the Ministry of Health of Ukraine), Help for Families from Chornobyl (an international association established in 1994 that provides medical and humanitarian aid), and Children of Chornobyl for Survival. The National Register contained 668 evacuees in the target age range, and the two relief organizations contributed 53 additional children, for a total of 721 children (576 children were on all 3 lists). Next, the addresses of the 721 children were checked, and 693 families were identified who were still living in Kyiv in 1996. Fifteen of the 693 children were randomly selected to participate in a pilot study. From the remaining 678 evacuee children, respondents were randomly selected until 300 interviews were completed.

The comparison group consisted of a same sex, non-evacuee child selected from the same classroom as each evacuee. Thus, they had the same teachers and daily schedule, and resided in similar apartment buildings. The contamination levels in Kyiv were substantially lower than those in the 30-kilometer zone where the evacuee children were from (Bard et al., 1997), although within each of these contrast areas, the contamination was extremely spotty.

The response rates were 92% for the evacuees and 85% for the classmates. The main reasons for refusal by evacuee families were many occasions of prior participation in research and fearing that the family would be traumatized by discussing the accident. The main reasons given by comparison families were lack of time and refusal by husbands to let their wives be interviewed.

The assessments took place in 1997 when the children were 10–12 years old. The mean age (and standard deviation) was 10.67 ± 0.60 years for the evacuee children and 10.87 ± 0.72 for the classmates; 48.3% of both groups were male.

Procedure

The study entailed home interviews with mothers and children during which the psychosocial and neuropsychological data were collected ($N = 600$). This was followed by physical

examinations and blood tests conducted at a clinic by physicians trained in the study protocol, and completion of developmental and medical history questionnaires by the mothers ($N = 547$). We note that except for one 11-year-old evacuee whose thyroid was removed 1 year prior to interview, no differences were found in the physical health of the two groups of children, and both groups were on the whole healthy except for the usual childhood illnesses. No child was in an institution. The third step entailed collection of school data from teachers and records.

The home interviews were conducted between February and May, 1997. The initial contact was made with the mothers either in person or by telephone. Written informed consent was obtained after a complete description of the study was given. The mothers were also provided with a letter indicating that they would receive feedback about the findings when the study was completed. This meeting took place in May 1998. In addition, the mothers and children received gifts at the conclusion of the interview and vitamins at the end of the physical examinations.

In order to gain access to the schools, we procured a letter from the Director of the Department of Education of Kyiv (B. M. Zhebrovsky) requesting cooperation from the principals. The interviewers went to the schools to obtain teacher ratings, attendance records, and current grades in May 1997.

Interviewer Training and Monitoring

The home interviews were organized by SOCIS-Gallop of Kyiv (founded in 1992). This organization has conducted numerous sociological and political surveys (public opinion polls, social-psychological surveys, etc.) as well as sociological and social-psychological studies of Chornobyl-exposed populations. The 20 interviewers were selected by EJB and NP. They were all university graduates, and 90% were scientists and teachers. They had experience in working on previous SOCIS projects and received extensive training for this project. Special attention was given to administration of the neuropsychological tests since this was the most unfamiliar aspect of the interview. EJB who has administered most of the tests used in this study, made a training video and conducted a training session in Kyiv. The Ukrainian and American teams worked closely to monitor the interview process throughout the fieldwork, including recontacting 10% of the sample to verify selected items, and independent checking of interview schedules by the field supervisor, working under the direction of NP, to identify and clarify missing data or inconsistent responses. In addition, the US investigators visited 20 randomly selected respondents to review the conduct of the study, and physical examinations were repeated with 9 children by an American physician to confirm the physical findings.

Measures

An initial English version of many of the measures was assembled at Stony Brook and translated into both Russian and Ukrainian. One instrument, the Child Behavior Checklist (CBCL), was already available in Russian (Carter, Grigorenko, & Pauls, 1995). Some items underwent revision due to cultural acceptability and local idioms. The final set of instruments was back-translated into English and reflects these modifications. The final battery of measures also contained instruments previously developed in Kyiv. Eighty per cent of mothers and 72% of the children were interviewed in Russian; the remainder were interviewed in Ukrainian.

This paper focuses on education, neuropsychological, and subjective measures. A brief neuropsychological battery was assembled that was as culture/language-free as possible and that could be administered reliably by lay interviewers. Five sets of measures were administered: an intelligence test (Symbolic Relations subtest of the Detroit Tests of Learning Aptitude; Hammil, 1991), tests of visual attention (two forms of the Visual Search and Attention Test; VSAT; Trenerry, Crosson, DeBoe, & Leber, 1990), a test of alertness and attention (Trails A, using the Ukrainian alphabet; Reitan, 1958), a Ukrainian-developed test of attention (Underline the Words test), and a test of visual memory and visual motor skill (the Benton Visual Retention Test A; Benton, 1974). School grades, teachers' and mothers' ratings of attention problems, and mothers' and children's perceptions of school performance were also included. Further description of these measures follow.

Objective measures.

(1) *School performance*. Second-quarter grades were obtained from school records for the following subjects: Ukrainian literature, Ukrainian language, foreign literature, foreign language, mathematics, and history (scaled 2 = bad; 3 = satisfactory; 4 = good; 5 = excellent). The intercorrelations among these grades were all between .50–.60, and they load on a single factor in a Principle Components Analysis using varimax rotation. Thus, we computed the grade point average (GPA) for each child, by taking the mean of these grades. In addition, we stratified the grades into low (less than 3.6, reflecting the lower third) and high (3.6+).

(2) *Intelligence*. The Symbolic Relations subtest of the Detroit Tests of Learning Aptitude was chosen to approximate intelligence level because it minimizes cultural bias by measuring the ability to reason and solve spatial problems without language (Hammil, 1991). The test involves 30 cards displaying a series of designs. The subject is required to select a corresponding design from six choices to complete a pattern. In an American sample, the Symbolic Relations subtest correlated well with the Wechsler Intelligence Scale for Children-Revised (WISC-R) Full Scale IQ ($r = .64$; Hammil, 1991). In our sample, the correlation between the Detroit subtest and school grades was $r = .28$ ($p < .001$), and there was a significant difference between children with low grades (mean Detroit = 16.3 ± 5.7) compared to children with higher grades (19.2 ± 5.8) ($p < .001$).

(3) *Attention*. Two forms of the VSAT (Lezak, 1995; Trenerry et al., 1990) were administered. The tasks involved showing the child a target letter and then a target symbol along with sheets of paper with many letters or symbols. The child was instructed to cross out as many appropriate characters as possible within 60 seconds. The total number correctly crossed out and the number of errors were determined for each test. Ninety per cent made no errors (failing to cross out appropriate characters or crossing out inappropriate characters) on the first test, and 88% made 0–1 errors on the second test. Thus, we focused on the number correctly crossed out. The correlation between the two tests was $r = .66$ ($p < .001$).

Trails A was administered to assess alertness and attention (Reitan, 1958). For Trails A, the children connected a series of numbers (1–25) in order, with a straight line, while the interviewer timed them. The clock was stopped when all the numbers were connected, and the number of seconds was recorded.

The "Underline the Words" test was developed in Kyiv and assesses attention. This test involved finding and underlining real words within a series of letters. Some of the words were related to the Chornobyl disaster. The number of correctly underlined words was used in the analysis.

(4) *Memory*. The Benton Visual Retention Test A was administered to assess visuoperceptive, visuomotor, and visual memory (Benton, 1974). This test was selected because it did not rely on language skills, thus minimizing cultural bias. The test involved showing the child 10 cards with figures on them. The children had 10 seconds to examine each card. They then drew the figure from memory. The scoring was done at Stony Brook. Each test was scored independently by two raters who were blind to the evacuee status of the subjects. All discrepancies were reconciled by NS. Two measures were obtained, the number of correct reproductions and the number of errors (such as drawing incorrect figures, failing to draw all figures, or misplacement of the figures). The correlation between these measures was r = .89; hence only the number of correct reproductions is analyzed below.

Subjective measures. Perception of school performance was assessed using the following question administered to the mothers and children: "How do you/does your child do in school?" A 5-point scale was used (5 = mostly As, 4 = As and Bs, 3 = mostly Bs, 2 = Bs and Cs, and 1 = mostly Cs). We note that the correlations between these subjective reports and actual school performance (GPA) were high ($r = .79$ and .74 for mothers' and children's reports of school performance and GPA, respectively). The correlation between mothers' and children's perceptions of grades was also high ($r = .72$).

The CBCL was included as part of the developmental and medical history questionnaire completed by the mothers (Achenbach, 1991). The attention subscale was used in this report to evaluate mothers' perceptions of the children's ability to concentrate and pay attention. This measure includes 11 items rated on a 3-point scale (0 = not at all, 1 = somewhat true, 2 = completely true). An example item is: "Can't sit still, restless or hyperactive." The internal reliability measured by Cronbach's alpha was .75.

In a separate section of this questionnaire, mothers were also asked whether their child had a problem with memory (yes; no).

The 10-item Iowa Conners Teacher's Rating Scale (Loney & Milich, 1982) was administered to homeroom teachers. The items were rated on a 4-point scale (0 = not at all to 3 = very much). Three items assessed attention problems (fidgeting, inattentive, and short attention span). For this report, the mean of the above three items was used to assess Teacher Rated Attention ($\alpha = .82$).

Additional Variables

Four additional sets of comparisons were performed: (1) Evacuee children ($N = 101$) who were *in utero* at the time of the explosion were compared with classmates ($N = 88$) who were *in utero* at that time (born between 27 April 1986 and 31 January 1987). (2) Within the group of evacuees, the 242 children from Pripyat, the town (population approx. 50,000) built near Chornobyl to house the workers and their families, were compared with the 58 children from small villages. (3) Evacuees and classmates reporting relatively more Chornobyl-focused anxiety were compared with their less symptomatic peers. The Chornobyl Anxiety Scale was adapted from the Modified Post-Traumatic Stress Disorder (PTSD) Reaction Index (Pynoos et al., 1987), and contained 15 items rated 0 = absent to 4 = always present ($\alpha = .86$). The scale included items such as "Do you get scared or upset when you think about Chornobyl?" and "Do you stay away from things that remind you about the accident?" The items were summed. The overall mean was 14.8 ± 9.7. The Chornobyl Anxiety Scale was categorized by dividing children into those scoring in the highest (most symptomatic) quintile (e.g. scores of 22 or more) and those scoring below this value. (4) Evacuees and classmates reporting relatively more general anxiety on The Children's Manifest Anxiety Scale (CMAS; Reynolds & Richmond, 1978) were compared to the less symptomatic children. The CMAS contains 28 items rated yes/no ($\alpha = .81$). Sample items are "I get nervous when things do not go the right way for me" and "I worry when I go to bed at night." The mean score was 13.0 ± 5.2. This scale was also categorized by dividing children into those scoring in the highest (most symptomatic) quintile (e.g. scores of 18 or higher) and those scoring below this value. The correlation between the Chornobyl Anxiety Scale and the CMAS was r = .29.

Statistical Analysis

Analysis of covariance was used for comparing the evacuee and classmate groups on the continuous variables, and logistic regression was used for the dichotomous variable (maternal report of memory problems). Because no Ukrainian normative data exist for the neuropsychological measures, and such tests are associated with age and (at times) sex in other settings (Lezak, 1995), the analyses presented below took age and sex into account. Specifically, a series of 2 (evacuee, classmate) by 2 (girl, boy) analyses of covariance (ANCOVA) adjusting for age was performed. Adjusted odds ratios are presented in the analysis of differences in reported memory problems. The CBCL attention subscale violated the assumption of normality and was log transformed. Twelve outliers on the Trails A, whose time was greater than 100 sec, were excluded for the analysis of this measure.

To further examine the effects of *in utero* status, and whether the evacuee family came from a village or Pripyat in the 30-kilometer zone, we repeated the analyses described above (except that estimated gestation month derived from the child's date of birth, rather than age, was a covariate in the analysis of the *in utero* subgroup). To analyze the effects of general and Chornobyl-focused anxiety, 2 (high vs. low anxiety) by 2 (evacuee vs. classmate group) by 2 (girl vs. boy) analyses of covariance, controlling for age, were performed.

To adjust for multiple comparisons, a Bonferroni corrected alpha level of $< .005$ was used to assess statistical significance (.05 divided by 11 comparisons within each target analysis).

Results

Objective Measures

The descriptive statistics for the objective measures of attention, memory, and intelligence appear in Table 1. All means and standard deviations listed are untransformed.

As seen in Table 1, there were no significant differences between evacuees and classmates on the objective measures used in this study. To emphasize this finding, Figs. 1a and 1b show the distributions for the Benton Visual Retention test A and "Underline the Words" (number correct). The distributions for each of these variables were bell-shaped and similar for both evacuees and classmates.

Table 1 shows that the grade point averages were similar. The proportion of evacuees with low grades (28.7%) was also similar to that of the classmates (30.7%). There were also no differences between the groups on any individual school subject (data not shown). The subject on which both groups had the lowest average performance was mathematics, and the best grades were found for Ukrainian literature.

We attempted to compare the children's performance on the various tests with normative data. Age appropriate normative data were available for the intelligence test (Symbolic Relations), one attention test (Trails A), and the visual memory test (Benton). For Symbolic Relations, the Ukrainian sample performed similarly to an American sample of the same age. Specifically, the means for an American normative sample ($N = 830$ children from 36 states assessed in 1984) were 18, 20, and 21 with a standard error of 1 for ages 10, 11 and 12, respectively. The distribution for our sample was 18 ± 6 for 10-year-olds ($N = 218$), 19 ± 6 for 11-year-olds ($N = 300$), and 18 ± 7 for 12-year-olds ($N = 81$). On Trails A, the Ukrainian sample was somewhat slower than the American norms. Only 30.5% of the 600 Ukrainian children were within the normal range of 7–43 sec reported for American 10–12-year-olds (Spreen & Strauss, 1991). We have no explanation for this discrepancy except that either the Ukrainian raters systematically timed the children inaccurately or the children did not understand

Table 1
Objective Measures of Attention, Memory, and Intelligence in 10–12-year-olds Evacuated to Kyiv after the Chornobyl Accident and a Classmate Comparison Group

	Evacuees ($N = 300$)		Classmates ($N = 300$)	
Objective measures[a]	Mean	*SD*	Mean	*SD*
Neuropsychological tests				
Intelligence				
Detroit Symbolic Relations	17.98	5.99	18.38	6.07
Attention				
VSAT: Letters # correct[b,c]	50.39	11.11	51.29	10.65
VSAT: Symbols # correct[b,c]	49.86	9.23	51.08	8.87
Trails A[c]	51.27	14.78	52.11	14.72
Underline the Words # correct[b]	11.25	3.84	11.41	3.75
Memory				
Benton # correct	6.26	1.76	6.23	1.72
School grades				
Overall GPA[b]	3.92	0.57	3.97	0.64

All means and *SD*s are untransformed.
[a] No significant group differences were found using 2 (group) by 2 (sex) analysis of covariance adjusting for age.
[b] Girls performed significantly better ($p < .001$) than boys on: VSAT letters [$F(1,595) = 44.56$], VSAT symbols [$F(1,595) = 19.14$], Underline the Words [$F(1,595) = 19.48$], and GPA [$F(1,592) = 35.10$].
[c] Older children performed significantly better ($p < .001$) than younger children on: VSAT letters [$F(1,595) = 32.30$], VSAT symbols [$F(1,595) = 31.28$], and Trails A [$F(1,583) = 15.46$].

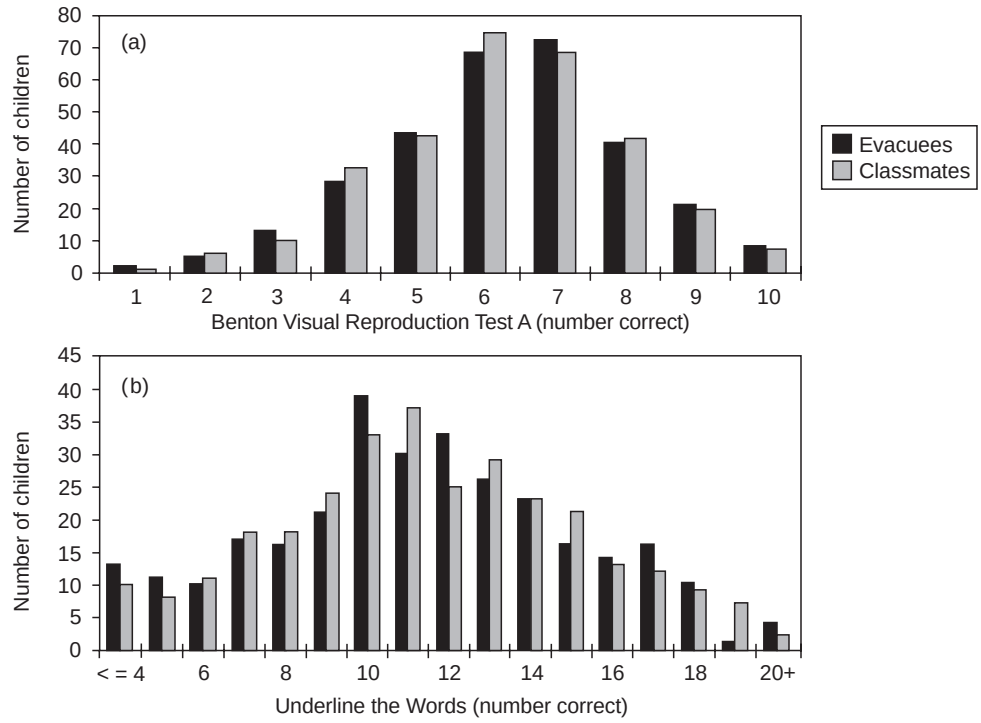

Figure 1. (a) Scores on Benton Visual Retention Test A; (b) scores on Underline the Words test.

that they were to work as fast as they possibly could. In terms of performance on the Benton, normative data were collected for 123 American children aged 10, 11, and 12 years old in 1961. For children with average IQ, the mean number correct was 5, 6, and 7, for ages 10, 11, and 12, respectively (Benton, 1974). The mean and standard deviation for the 10-, 11-, and 12-year-olds in the Ukrainian sample was 6 ± 2 within each age group.

It should be emphasized that the measures presented in Table 1 were only modestly intercorrelated (*r*s between .20 and .30). The correlations between school grades and neuropsychological test performance were mostly under .30, with the exception of Underline the Words and grade point average ($r = .44$; $p < .001$). Thus, the failure to find significant group differences across these variables cannot be attributed to redundancy of the measures.

Subjective Measures

No significant differences were found in the mothers' perception of their children's grades (mean $\pm$ standard deviation $= 3.14 \pm 1.06$ for evacuees vs. 3.27 ± 1.11 for

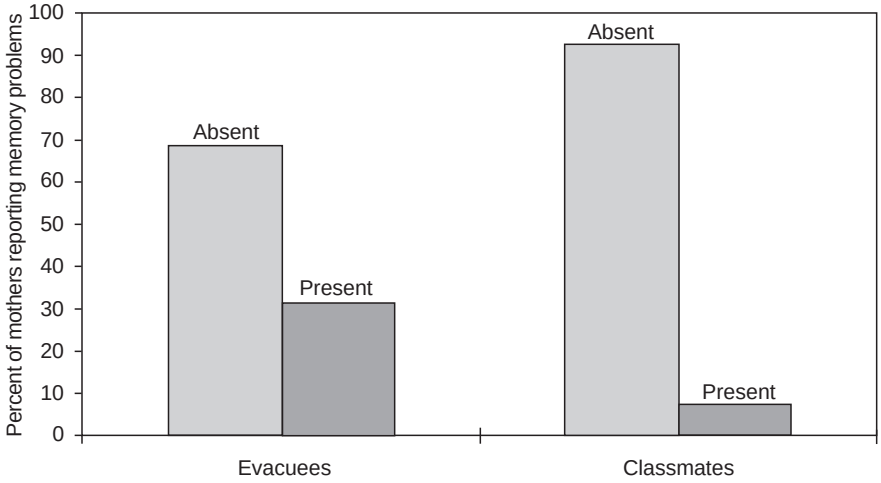

Figure 2. Percentage of evacuee and classmate mothers who reported memory problems in their children.

comparison children) or the CBCL attention subscale (60.43 ± 7.80 vs. 59.03 ± 7.79). The CBCL values are similar to those found in a sample near Moscow (Carter et al., 1995). Similarly, the children's perceptions of their grades were not different in the two groups (3.10 ± 0.96 vs. 3.21 ± 1.06). Finally, the teachers' perceptions of attention problems were also similar (0.87 ± 0.80 for evacuees vs. 0.82 ± 0.80 for classmates). We note that for every variable except the CBCL, girls were perceived as performing significantly better than boys, and age was not significant.

The one variable on which the groups differed significantly was the mothers' report of memory problems in their children, with 31.3% (86/275) of evacuee mothers vs 7.4% (20/272) of comparison group mothers indicating this problem (Fig. 2). The adjusted odds ratio (adjusted for age and sex) was 7.7 (confidence interval 3.3–18.0). It is noteworthy that mother-reported memory problems were not significantly associated with performance in school or with neuropsychological test scores (based on a series of 2 [evacuee, classmate] by 2 [memory problems present or absent] by 2 [girl, boy] analyses of covariance, controlling for age). There were also no significant effects of age or sex.

Additional Analyses

In utero subgroup. Using a 2 (group) by 2 (sex) analysis of covariance (controlling for estimated gestation month at the time of the explosion), we found no significant differences between *in utero* evacuee and comparison children. Logistic regression was used to analyze the relationship with maternal report of child memory problems and group status. Consistent with the findings from the full sample, significantly ($p < .001$) more evacuee (30.0%) than comparison mothers (7.4%) reported memory problems in the children (odds ratio adjusted for sex and gestational age = 5.25; confidence interval = 2.03–13.55). Gestational age was not a significant covariate in any of the above analyses.

Pripyat. The children from Pripyat families were not significantly different from the children from contaminated villages on any of the measures in this report. The only variable that was even marginally different ($p = .06$) was the intelligence test (Symbolic Relations), on which the village children had slightly better scores (mean 19.3 ± 6.3) than children from Pripyat (mean 17.7 ± 5.9).

Chornobyl anxiety. Overall, the children with greater Chornobyl-focused anxiety had poorer functioning ($p < .02$) on 3 of the 13 measures, Trails A, the teacher attention scale, and Underline the Words, but these differences were not significant at the Bonferroni corrected alpha level of .005, and importantly, there were no significant interactions between Chornobyl-anxiety and evacuee/classmate group (Table 2). The analysis was repeated with the *in utero* subgroup, and no significant differences in Chornobyl anxiety were found.

General anxiety. With one exception, the children with greater anxiety in general, based on performance on the CMAS, functioned similarly to children with less general anxiety. The exception was the CBCL attention scale, on which higher anxiety children were rated by their mothers as being more symptomatic (CBCL mean for high anxiety group = 61.28 ± 8.5; CBCL mean for low anxiety group = 59.31 ± 7.68; $F(1,537) = 7.74$; $p = .006$). However, although statistically significant, the absolute difference between these two means is very small. The analyses were repeated with the *in utero* subgroup, and no significant effects of general anxiety were found.

Discussion and Conclusions

The results reported here show that, contrary to reports about cognitive and neuropsychological impairment, the evacuee children who participated in the Stony Brook-Kyiv Chornobyl project performed as well as classmates on a set of objective tests of attention, memory, and intelligence. This was also found for the children who were *in utero* at the time of the explosion. On the other hand, more evacuee mothers subjectively reported memory problems in their children than classmates' mothers, but these reports were not correlated with performance on the neuropsychological tests or grades in school.

The present study was designed to overcome many of the methodological problems plaguing studies of technological disasters. Specifically, considerable efforts went into assembling a sampling frame that was as complete as possible. The classmate comparison group lived in very similar circumstances to the evacuees. The response rate was high. Most importantly, we included both objective

Table 2
Comparison of Evacuee and Classmate Children According to the Level of Chornobyl-focused Anxiety[a]

	Evacuee children		Classmates	
Measures	High Chornobyl anxiety ($N = 78$)	Low Chornobyl anxiety ($N = 221$)	High Chornobyl anxiety ($N = 54$)	Low Chornobyl anxiety ($N = 246$)
Neuropsychological Tests/GPA				
Detroit Symbolic Relations	16.86 ± 6.03	18.38 ± 5.98	18.56 ± 6.50	18.34 ± 5.98
VSAT: Letters # correct	48.65 ± 12.47	51.32 ± 11.01	51.17 ± 8.89	51.32 ± 11.01
VSAT: Symbols # correct	49.88 ± 9.47	51.24 ± 9.13	50.35 ± 7.59	51.24 ± 9.13
Trails A[b]	52.87 ± 13.03	59.71 ± 15.37	55.77 ± 14.53	51.31 ± 14.67
Underline the Words # correct[c]	10.68 ± 3.76	11.54 ± 3.74	10.81 ± 3.74	11.54 ± 3.74
Benton # correct	6.01 ± 1.97	6.36 ± 1.68	6.28 ± 1.85	6.22 ± 1.69
GPA	3.85 ± 0.58	3.94 ± 0.56	3.94 ± 0.67	3.98 ± 0.64
Perception of grades:				
Child's self-report	2.96 ± 0.96	3.15 ± 0.96	3.11 ± 1.06	3.23 ± 1.06
Mothers' report	3.05 ± 1.09	3.17 ± 1.05	3.07 ± 1.10	3.31 ± 1.12
Perception of attention				
Teacher-rated attention[d]	0.92 ± 0.75	0.85 ± 0.82	1.02 ± 0.87	0.78 ± 0.78
Mother-rated attention (CBCL)	61.32 ± 7.90	60.11 ± 7.77	60.12 ± 7.81	58.77 ± 7.79

[a] High anxiety defined as scoring in the top quintile, i.e. $\geqslant 22$.
[b] Significant difference between high and low anxiety level: $F(1,578) = 5.99$; $p = .02$.
[c] Significant difference between high and low anxiety: $F(1,590) = 5.16$; $p = .02$.
[d] Significant differences between high and low anxiety level: $F(1,587) = 5.75$; $p = .02$.

and subjective measures in the test battery. On the other hand, the limitations of the study included the fact that the interviewers were not experienced in administering these kinds of tests, which may have contributed to the slower than expected performance of the children on Trails A. No specific data on radiation exposure were available. Finally, there are no normative data in Ukraine for the measures used in this report.

Similar research has been done on the cognitive status of pediatric cancer patients who have undergone radiation treatment, and the results have been inconsistent. Mulhern, Ochs, and Fairclough (1992) compared long-term, pediatric leukemia survivors who either received chemotherapy or cranial irradiation. The Wechsler Preschool and Primary Scale of Intelligence (WPPSI) or the Wechsler Intelligence Scale for Children-Revised (WISC-R) were age-appropriately administered to assess IQ. They found no significant decrease in IQ from the time of the first testing session (0–30 months from diagnosis) to the two follow-up testing sessions (31–54 months, and more than 54 months from diagnosis) in the two groups (Mulhern et al., 1992). Simms, Kazak, Gannon, Goldwein, and Bunin (1998) administered neuropsychological examinations at the time of diagnosis and at a 1-year follow-up to pediatric cancer patients who either underwent chemotherapy only or chemotherapy plus total body irradiation in preparation for a bone marrow transplant. They also found no significant differences between the two groups at follow-up, and almost all neuropsychological measures either stayed the same or improved from time 1 to time 2 for both groups (Simms et al., 1998). In contrast, Smedler, Nilsson, and Bolme (1995) found that cancer patients between the ages of 3–11 ($N = 15$), treated with radiation, showed declines over time on tests of perceptual and fine-motor skills as well as nonverbal problem solving, whereas older cancer patients, aged 12–17 ($N = 11$), showed stable performance (Smedler et al., 1995).

As noted earlier, two studies reported higher rates of cognitive impairment in children exposed to radiation from Chornobyl compared to controls (Kolominsky et al., 1999; Nyagu et al., 1998). However, differences between the two studies make interpretation and generalization of the results difficult. Although both studies focused on children who were *in utero* at the time of the accident, the children in the Kolominsky et al. study remained in a highly contaminated area for 5–7 years after the accident. Also, each study assessed intellectual performance using different measures (Kolominsky et al. administered the Wechsler Intelligence Scale for children; Nyagu et al. used the Draw a Man test, Raven Colored Matrices, and the British Picture Vocabulary Scale). Kolominsky et al. concluded that their findings could have been due to socioeconomic differences between the exposed and control sites, whereas Nyagu et al. attributed their findings to a combination of unfavorable circumstances in the aftermath of the disaster and radiation exposure. However, as noted earlier, it is unclear how the latter study reconstructed radiation dosage.

It should be emphasized that our target sample is composed of children evacuated from the 30-km zone to Kyiv shortly after the accident, whereas Kolominsky et al. (1999) focused on children who remained in the contaminated area for 5–7 years. Moreover, unlike the Kolominsky et al. control group, which was socioeconomically different, our control group was similar in terms of lifestyle and schooling. Thus, the samples differed both in terms of the risk groups' duration of exposure and the nature of the comparison that was being made.

Although Kyiv was far less contaminated by radiation

than the evacuated areas, the Kyiv classmates provide a conservative comparison group because many people living in Kyiv believe that they were exposed to high levels of radiation. However, the fact remains that both groups of children in our study, including the *in utero* subgroup, performed well in school and on the neuropsychological tests we administered.

Saigh et al. (1997) suggested that disaster-exposed children with post-traumatic stress symptoms are at risk for scholastic impairment. We thus examined whether generalized or Chornobyl-focused anxiety was related to grade point average or neuropsychological test performance. Although general anxiety was not associated with these measures, there was a tendency overall for greater Chornobyl anxiety to be associated with slightly poorer performance on three measures of attention. However, the children's actual grades did not appear to be influenced by anxiety. We note that the Saigh et al. research was conducted with children exposed to war, a more immediate and direct exposure.

There are certain similarities between disasters involving radiation and those involving other toxins. Both pose a number of complications with respect to identification of the nature of the effects on exposed persons. The potential biological effects of the toxin are complicated by effects of disaster stress, and interactions between the two (Havenaar & van den Brink, 1997). Therefore, anecdotal reports of impairment in evacuee children might be attributed to disaster and resettlement stress, on either mother or child, or to the unknown effects of radiation. The fact that the evacuee mothers reported more memory problems than did classmate mothers was thus not surprising. We hypothesize that these reports were associated with mother's anxiety. However, the present results provide no support for the presumption of cognitive or neuropsychological differences between the two groups of children.

Acknowledgements—This research was supported by Grant No. MH51947 from the National Institute of Mental Health. We wish to thank N. Churilov, Director of SOCIS-Gallop in Kyiv and the field staff for conducting the assessments and A. Gorbatchik of Kyiv Taras Shevchenko University, for organizing the data management system; T. Gilbert, M. Abramova, and V. Grigorenko for organizing the conducting of physical examinations, and D. Gluzman and S. Lyubsky for conducting the blood tests. We are very grateful to Ints Calitis and Sergey Fedorinchik for introducing our project to key professionals and parent organizations in Kyiv. Several individuals at the State University of New York at Stony Brook provided important support for this study, including Drs Lynda Geller and Joseph Schwartz, Elena Polenova, Inna Korchack, and Lina Jandorf. Most of all, we are grateful to the children and mothers who participated in this study.

References

Achenbach, T. M. (1991). *Manual for the CBCL/4–18 and 1991 profile*. Burlington, VT: University of Vermont, Department of Psychiatry.

Aptekar, L., & Boore, J. A. (1990). The emotional effects of disaster on children: A review of the literature. *International Journal of Mental Health*, *19*, 77–90.

Bard, D., Verger, P., & Hubert, P. (1997). Chernobyl 10 years after: Health consequences. *Epidemiologic Reviews*, *19*, 187–204.

Benton, A. L. (1974). *Revised Visual Retention Test* (4th ed.). New York: The Psychological Corporation.

Breton, J., Valla, J., & Lambert, J. (1993). Industrial disaster and mental health of children and their parents. *Journal of the American Academy of Child and Adolescent Psychiatry*, *32*, 438–445.

Bromet, E. J. (1995). Methodological issues in designing research on community-wide disasters with special reference to Chernobyl. In W. E. Hobfoll & M. W. deVries (Eds.). Extreme stress and communities: Impact and intervention (pp. 267–281). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Bromet, E. J., & Dew, M. A. (1995). Review of psychiatric epidemiologic research on disasters. *Epidemiologic Review*, *17*, 113–119.

Bromet, E. J., Hough, L., & Connell, M. (1984). Mental health of children near the Three Mile Island reactor. *Journal of Preventive Psychiatry*, *2*, 275–301.

Carter, A. S., Grigorenko, E. L., & Pauls, D. L. (1995). A Russian adaptation of the Child Behavior Checklist: Psychometric properties and associations with child and maternal affective symptomatology and family functioning. *Journal of Abnormal Child Psychology*, *23*, 661–684.

Goldman, M. (1997). The Russian radiation legacy: Its integrated impact and lessons. *Environmental Health Perspectives*, *105*, 1385–1391.

Hammil, D. D. (1991). *Detroit Tests of Learning Aptitude* (3rd ed.). Austin, TX: Pro-Ed.

Havenaar, J. M., & van den Brink, W. (1997). Psychological factors affecting health after toxicological disasters. *Clinical Psychology Reviews*, *17*, 359–374.

Kolominsky, Y., Igumnov, S., & Drozdovitch, V. (1999). The psychological development of children from Belarus exposed in the prenatal period to radiation from the Chernobyl atomic power plant. *Journal of Child Psychology and Psychiatry*, *40*, 299–305.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Loney, J., & Milich, R. (1982). Hyperactivity, inattention, and aggression in clinical practice. In M. Wolraich & D. K. Routh (Eds.), *Advances in developmental and behavioral pediatrics*, *Vol. 3* (pp. 113–147). Greenwich, CT: JAI Press.

Mulhern, R. K., Ochs, J., & Fairclough, D. (1992). Deterioration of intellect among children surviving leukemia: IQ test changes modify estimates of treatment toxicity. *Journal of Consulting and Clinical Psychology*, *60*, 477–480.

Nyagu, A. I., Loganovsky, K. N., & Loganovskaja, T. K. (1998). Psychophysiologic after-effects of prenatal irradiation. *International Journal of Psychophysiology*, *30*, 303–311.

Pynoos, R. S., Frederick, C., Nader, K., Arroyo, W., Steinberg, A. Spencer, E., Nunez, F., & Fairbanks, L. (1987). Life threat of post-traumatic stress disorder in school-age children. *Archives of General Psychiatry*, *44*, 1057–1063.

Reitan, R. M. (1958). Validity of the Trail Making test as a indicator of organic brain damage. *Perceptual and Motor Skills*, *8*, 271–276.

Reynolds, C. R., & Richmond, B. O. (1978). What I think and feel: A revised measure of Children's Manifest Anxiety. *Journal of Abnormal Child Psychology*, *6*, 271–280.

Saigh, P. A., Mroueh, M., & Bremner, J. D. (1997). Scholastic impairments among traumatized adolescents. *Behaviour Research and Therapy*, *35*, 429–436.

Saylor, C. (1993). Children and disasters: Clinical and research issues. In C. Saylor (Ed.), *Children and disasters*. New York: Plenum Press.

Shcherbak, Y. (1996). Ten years of the Chornobyl era. *Scientific American*, *274*, 44–49.

Simms, S., Kazak, A. E., Gannon, T., Goldwein, J., & Bunin, N. (1998). Neuropsychological outcome of children undergoing bone marrow transplantation. *Bone Marrow Transplantation*, *22*, 181–184.

Smedler, A. C., Nilsson, C., & Bolme, P. (1995). Total body irradiation: A neuropsychological risk factor in pediatric bone marrow transplant recipients. *Acta Paediatrica*, *84*, 325–330.

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests*. New York: Oxford University Press.

Trenerry, M. R., Crosson, B., DeBoe, J., & Leber, W. R. (1990). *Visual Search and Attention Test*. Odessa, FL: Psychological Assessment Resources.

Vogel, J. M., & Vernberg, E. M. (1993). Children's psychological responses to disasters, part I. *Journal of Clinical and Child Psychology*, *22*, 464–484.

Yule, W., Udwin, O., Murdoch, K. (1990). The "Jupiter" sinking: Effects on children's fears, depression and anxiety. *Journal of Child Psychology and Psychiatry*, *31*, 1051–1061.

Manuscript accepted 5 October 1999