

Effects of a Large-Scale Industrial Disaster on Rates of Symptoms Consistent With Posttraumatic Stress Disorders Among Schoolchildren in Toulouse

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Background: Posttraumatic stress disorder (PTSD) has been studied largely among adults and in the context of intentional, collective experiences such as war and terrorism. Far less is known about PTSD among adolescents and resulting from massive industrial accidents. Such an accident in Toulouse, France, 10 days after the World Trade Center disaster, provided an opportunity to examine its effects among adolescents already sensitized by media coverage of the World Trade Center disaster.

Objectives: (1) To assess the presence of symptoms consistent with PTSD (SCW-PTSD) among adolescents in Toulouse after a massive industrial accident, (2) to determine the “excess” of SCW-PTSD among those directly exposed vs those nondirectly exposed, and (3) to examine dosage effects for exposure and the cumulative effect on PTSD of accident-related experiences.

Design, Setting, and Participants: A survey containing questions on exposure and SCW-PTSD was administered to students aged 11 years, 13 years, 15 years, and 17 years who were enrolled in randomly selected, grade-stratified classrooms from schools for directly exposed students (n=577) in Toulouse and nondirectly exposed students (n=900) in the region.

Main Outcome Measure: The prevalence of SCW-PTSD among directly exposed and nondirectly exposed students.

Results: Nine months after the industrial accident, 44.6% of 11- and 13-year-old directly exposed students and 28.5% of 15- and 17-year-old directly exposed students

still showed SCW-PTSD, compared with 22.1% of 11- and 13-year-old nondirectly exposed students and 4.4% of 15-year-old nondirectly exposed students. Among 11- and 13-year-olds, the likelihood of having SCW-PTSD was higher for girls who were enrolled in elementary schools, were personally injured, and had severe damage at home, as opposed to boys who were high-school students without severe damage at home or personal injury. Among the 15- and 17-year-olds, being a girl, 17 years old, and personally injured increased the likelihood of having SCW-PTSD, as opposed to 15-year-old boys who were not injured. The effects of injuries were cumulative: students injured personally and with an injured family member were more likely to have SCW-PTSD than those experiencing either personal or family injury but not both. Excess of SCW-PTSD attributable to direct exposure was 50.5% for 11-year-olds, 49.3% for 13-year-olds, and 73.5% for 15-year-olds.

Conclusions: A substantial proportion of Toulouse adolescents still had SCW-PTSD 9 months after the accident. Directly exposed students were far more likely to show SCW-PTSD than those nondirectly exposed, but both groups had SCW-PTSD at rates that were higher than expected. The symptoms were associated with demographic characteristics and direct experiences of trauma. Higher rates applied to students who were personally injured with injured family members and severe damage at home. Students with these characteristics predictive of SCW-PTSD should be given prompt attention to avoid long-lasting effects.

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ON SEPTEMBER 21, 2001, 10 days after the terrorist attack on the World Trade Center, a chemical factory, the AZF, exploded in a densely populated suburb of Toulouse, France, causing a tremor of 3.4 on the Richter scale. The shock wave spread throughout town, damaging residential and public buildings. Windows exploded miles away, and a toxic cloud spread toward the northwest. The AZF explosion was among the most serious industrial accidents in Europe since World War II: the numbers

included 30 people dead, 2242 people with injuries requiring hospital treatment, and 782 people hospitalized. Many schoolchildren were at risk of injury because of 31 damaged high schools (22 000 students) and 74 damaged elementary schools (12 000 students). During the ensuing period, elementary schoolchildren asked to make drawings of what transpired in Toulouse tended to blur the AZF and World Trade Center tragedies, showing the AZF factory with 2 towers instead of the 1 it had or showing an airplane crashing into the AZF tower.

In May and June 2002, approximately 9 months later, educational authorities in the Midi-Pyrénées region conducted a study to assess the disaster's impact on schoolchildren and to plan and prioritize follow-up care of the exposed population.

To provide a basis for comparison, the study piggybacked onto the cross-national Health Behavior in School-Aged Children (HBSC) survey,¹ conducted every 4 years since 1982 under the auspices of the World Health Organization Regional Office for Europe (Copenhagen, Denmark), targeting in-school youth aged 11 years, 13 years, and 15 years. The current study offered a rare opportunity to assess under natural conditions the impact of an explosion on rates of symptoms consistent with posttraumatic stress disorder (SCW-PTSD) among representative samples of directly exposed and nondirectly exposed schoolchildren.

METHODS

PARTICIPANTS

Toulouse has about 400 000 inhabitants, with 48 high schools and 184 elementary schools. Midi-Pyrénées, of which Toulouse is the capital, is the largest French region (larger than Switzerland or the Netherlands), with a population of 2 612 707, including approximately half a million schoolchildren.

Directly exposed schoolchildren were those enrolled in schools in the proximal zone (experiencing the highest levels of household damage²). All schools in the proximal zone (35 pre-elementary and elementary schools, 8 high schools) were damaged and closed for a period after the explosion (longer than a year for 2 vocational high schools). Of the 9975 children enrolled in these schools, about 3500 fell into the 3 HBSC-targeted age groups plus 17-year-olds; of these, 577 selected directly exposed adolescents provided analyzable data.

The comparison group of nondirectly exposed students was drawn from that portion of the nationally representative HBSC sample enrolled in schools from the Midi-Pyrénées region in comparable age groups ($n=50\,000$). We excluded from our analysis the sampled students who were potentially directly exposed based on their proximity to the blast zone or the path of the chemical cloud, leaving 900 respondents.

The 2 populations were well matched demographically, although those from the proximal zone had somewhat lower socioeconomic characteristics (a lower level of education, lower income, and higher rate of unemployment). We maintained comparability through a similarity of survey conditions and methods and comparably high response rates between groups.

SAMPLING DESIGN

In the directly exposed group, classes were sampled randomly from all the high schools in the proximal zone. Because 2 vocational schools were located in this zone, we also included 17-year-olds in the directly exposed group. For elementary schools, we first sampled schools and then randomly selected classes within the schools.

Following HBSC protocol, the nondirectly exposed (comparison) group represented a regionally representative sample in Midi-Pyrénées. We chose schools following a 2-stage sampling design, first selecting schools using probabilities proportional to size-sampling methods and then selecting classrooms within schools with equal probabilities of selection across classes. (A full description of the 2001 through 2002 HBSC

sample design and statistical requirements is available elsewhere.¹) As indicated earlier, potentially exposed children were removed from the nondirectly exposed group to provide a valid comparison group.

MEASUREMENT METHODS

An anonymous questionnaire was administered in classrooms, after receipt of parental permission, under the supervision of a psychologist in May and June 2002. The questionnaire included standard HBSC questions (eg, demographics, health and well-being, family and peer relationships, school environment, substance use). It also asked questions to elicit student self-reports of exposure: damage at home (no/yes/yes—severe enough to move); personal injury (no/yes); after-effects of injuries shown by scars or impairment (no/yes); injured people in family (no/yes/yes—severe); injured friends (no/yes/yes—severe); and scaled indicators of SCW-PTSD. For analytical purposes, we sometimes combined the 2 levels of “yes” for injuries.

For children younger than 15 years, we chose the Horowitz scale³ adapted by Dyregrov and Yule,⁴ the Revised Impact of Events Scale (R-IES). This scale, complete yet shorter than the initial Horowitz scale, is a self-report scale designed to measure symptoms of intrusion (4 items), avoidance (4 items), and arousal (5 items). The latter items have not been used as widely as the validated measures of intrusion and avoidance. The R-IES has been used among children exposed to war^{1,2} but never in French. The global score is calculated as the sum of 13 symptoms of PTSD (Cronbach $\alpha=0.77$) experienced “in the past 7 days” on a scale of 0 to 5 with the following response categories: not at all (0), rarely (1), sometimes (3), and often (5). A score greater than or equal to 17 on the 8 items relating to intrusion and avoidance has been found to be an efficient cutoff to assess PTSD.^{5,6} Using this cutoff, R-IES is efficient in discriminating cases with specificity and sensitivity at 90%. However, we recommend clinical tests to assess diagnosis.

For ages 15 years and older, we chose the Impact of Events Scale—Revised (IES-R) because the authorities in Toulouse selected it to monitor levels of PTSD among exposed adults.^{2,7} This scale is a revision of the Horowitz scale by Weiss and Marmar⁸: 7 new items evaluating arousal are added to the 15 original items. These new items have yet to be validated in English, but a French translation of the full scale was validated among Canadian women.⁹ The score is calculated as the sum of 22 symptoms of PTSD (Cronbach $\alpha=0.95$) experienced “in the past 7 days” on a scale of 0 to 4 with the following response categories: not at all (0), a little (1), some (2), much (3), and very much (4). For this scale, a cutoff of 33 was found to provide the best diagnostic accuracy when investigated in 2 samples of male Vietnam veterans.¹⁰

We computed the ratio of PTSD prevalence between directly exposed and nondirectly exposed students to estimate the excess of SCW-PTSD among those directly exposed to the explosion.

STATISTICAL ANALYSES

A small number of students with missing values on the PTSD scales were excluded from analysis. We conducted univariate and bivariate analyses on levels of exposure and SCW-PTSD, the 2 key outcome measures being the mean score and the percentage above the cutoff (considered the SCW-PTSD prevalence). All comparisons were assessed by *t* test or χ^2 test. Logistic regressions were performed against the dichotomous outcome of showing SCW-PTSD or not.

Table 1. Levels of Exposure by Age Group

Exposure	11-Year-Olds	13-Year-Olds	15-Year-Olds	17-Year-Olds
Severe damages at home, No.	199	116	140	91
Yes, %	29.1	35.3	33.6	28.6
No, %	70.9	64.7	66.4	71.4
Personal injuries, No.	193	114	139	92
Yes, %	13.0	21.0	18.7	43.5
No, %	87.0	79.0	81.3	56.5
Severely injured people in family, No.	190	107	133	91
Yes, %	8.9	15.9	9.8	9.9
No, %	91.1	84.1	90.2	90.1
Severely injured friends, No.	187	112	133	89
Yes, %	12.8	16.1	21.8	36.0
No, %	87.2	83.9	78.2	64.0

Explanatory variables included demographics (sex, age group) and exposure measures (severe damage at home, personal injury, severely injured family members or friends). All analyses were stratified on age groups (11- and 13-year-olds or 15- and 17-year-olds). Statistical analyses were conducted with SAS release 8.2 (SAS Institute Inc; Cary, NC). We computed confidence intervals with SUDAAN release 8.0.2 (Research Triangle Institute; Research Triangle Park, NC) to take into account the clustering effects inherent in the sampling design.

RESULTS

Comparable participation rates of 78.3% among directly exposed students and 80.0% among nondirectly exposed students eliminated differential response rates as an alternative explanation for any observed differences.

POPULATION CHARACTERISTICS

Among directly exposed students (293 boys, 284 girls), 35.7% were 11 years old, 22.2% were 13 years old, 25.6% were 15 years old, and 16.5% were 17 years old. Among nondirectly exposed students (450 boys, 450 girls), 32.3% were 11 years old, 28.7% were 13 years old, and 39.0% were 15 years old.

LEVELS OF EXPOSURE (DIRECTLY EXPOSED POPULATION)

When the explosion occurred (about 10 AM), 84.8% of surveyed students were in school, and 54.3% were in class. **Table 1** presents the exposure distribution by age group, where the level of exposure was evaluated through damage at home and injuries to self, family, or friends. Overall, 81.3% reported damage at home (at least broken windows), including 31.5% whose homes had severe damage. More than one fifth of students reported injuries, of whom 54.6% claimed aftereffects 9 months after the explosion. Two thirds of the 17-year-olds were in the 2 completely damaged high schools, hence more physically exposed than the others (43.5% were injured, 59.0% of whom experienced aftereffects). One quarter reported injured family members, of whom 40.9% were severely injured, and one half reported injured friends, of whom

21.3% were severely injured. As expected, it is among the oldest that we found the higher reported rates of injured friends (82.2%).

PTSD SCALES

Table 2 presents the mean score for SCW-PTSD in each age group and the associated 95% confidence interval among directly exposed and nondirectly exposed students. **Table 3** presents similar comparisons on the prevalence of SCW-PTSD, as defined in the "Methods" section.

R-IES: 11- AND 13-YEAR-OLDS

Directly exposed 11-year-olds had slightly higher mean scores and prevalence rates of SCW-PTSD than 13-year-olds. In both ages, there were no significant sex differences regarding those results. The pattern was the same among nondirectly exposed students. As expected, differences between directly and nondirectly exposed children were significant for the 2 criteria overall and separately for boys and girls in both age groups.

IES-R: 15- AND 17-YEAR-OLDS

Directly exposed 17-year-olds had much higher mean scores and prevalence rates of SCW-PTSD than 15-year-olds. In both ages, scores or prevalence were at least twice as high for girls than for boys. Among nondirectly exposed 15-year-olds, girls again had significantly higher results than boys. Among 15-year-olds, the differences between the 2 exposure groups were significant for the 2 criteria. As explained in the "Methods" section, directly exposed 17-year-olds could not be compared with nondirectly exposed counterparts.

EXCESS OF SCW-PTSD AMONG DIRECTLY EXPOSED STUDENTS

Among 11- and 13-year-olds, SCW-PTSD were twice as high among directly exposed students than among nondirectly exposed students. Among 15-year-olds, the ratio went up to 4 times. In all age groups, this ratio was

Table 2. Symptoms Consistent With Posttraumatic Stress Disorder by Age Group and by Sex Among Directly Exposed and Nondirectly Exposed Students

Group	Directly Exposed		Nondirectly Exposed	
	No.	Mean Score (95% Confidence Interval)	No.	Mean Score (95% Confidence Interval)
11-year-olds	165	23.4 (19.8-27.0)	256	14.3 (12.6-16.0)
Boys	84	21.8 (19.3-24.3)	130	14.3 (11.6-17.0)
Girls	81	25.0 (18.7-31.3)	126	14.3 (11.6-17.0)
13-year-olds	104	21.4 (17.4-25.4)	220	12.4 (10.2-14.6)
Boys	50	21.2 (17.2-25.2)	112	12.8 (9.8-15.8)
Girls	54	21.6 (17.1-26.1)	108	11.9 (9.2-14.6)
15-year-olds	84	17.4 (12.8-22.0)	294	8.3 (6.9-9.7)
Boys	43	11.2 (5.6-16.8)	151	6.4 (4.9-7.9)
Girls	41	24.0 (19.6-28.4)	143	10.3 (7.9-12.7)
17-year-olds	74	28.5 (14.9-42.1)	NA	NA
Boys	42	19.6 (16.2-23.0)	NA	NA
Girls	32	40.3 (30.3-50.3)	NA	NA

Abbreviation: NA, not applicable.

Table 3. Symptoms Consistent With Posttraumatic Stress Disorder by Age Group and by Sex Among Directly Exposed and Nondirectly Exposed Students

Group	Directly Exposed		Nondirectly Exposed	
	No.	Score Above Cutoff, % (95% Confidence Interval)	No.	Score Above Cutoff, % (95% Confidence Interval)
11-year-olds	165	47.3 (40.1-54.5)	256	23.4 (17.7-29.1)
Boys	84	45.2 (35.9-54.5)	130	24.6 (16.3-32.9)
Girls	81	49.4 (32.8-66.0)	126	22.2 (15.9-28.5)
13-year-olds	104	40.4 (30.0-50.8)	220	20.5 (14.7-26.3)
Boys	50	34.0 (24.5-43.5)	112	17.9 (11.0-24.8)
Girls	54	46.3 (31.2-61.4)	108	23.1 (14.1-32.1)
15-year-olds	84	16.7 (8.0-25.4)	294	4.4 (0.0-7.0)
Boys	43	4.7 (0.0-12.2)	151	2.0 (0.0-4.2)
Girls	41	29.3 (21.7-36.9)	143	7.0 (1.7-12.3)
17-year-olds	74	41.9 (15.5-68.3)	NA	NA
Boys	42	26.2 (14.0-38.5)	NA	NA
Girls	32	62.5 (46.5-78.5)	NA	NA

Abbreviation: NA, not applicable.

Table 4. Symptoms Consistent With Posttraumatic Stress Disorder Among 11- and 13-Year-Olds by Kind of Exposure

Exposure	Yes		No		P Value
	No.	Score Above Cutoff, %	No.	Score Above Cutoff, %	
Severe damages at home	85	54.1	183	40.4	.04
Personal injuries	40	57.5	220	42.7	.08
Severely injured people in family	30	56.7	222	44.1	.19
Severely injured friends	32	59.4	224	42.4	.07

higher for girls than for boys (11-year-olds, 1.8 vs 2.2; 13-year-olds, 1.9 vs 2.0; 15-year-olds, 2.4 vs 4.2). In other words, the excess of SCW-PTSD attributable to direct exposure to the accident was 50.5% for 11-year olds, 49.3% for 13-year-olds, and 73.5% for 15-year-olds.

SCW-PTSD AND EXPOSURE

Among 11- and 13-year-olds, the only exposure variable that significantly increased SCW-PTSD was severe

damage at home (**Table 4**). Among 15- and 17-year-olds, personally injured students showing aftereffects and having severely injured people in the setting showed significantly higher rates of SCW-PTSD (**Table 5**).

Moreover, the cumulative impact of individual and family injuries on such symptoms is noteworthy ($P < .001$). The proportion of students reporting SCW-PTSD went from 18.4% among those with no injuries (neither themselves nor in their families) to 30.4% among those with injured family members only, to 40.0% among those

Table 5. Symptoms Consistent With Posttraumatic Stress Disorder Among 15- and 17-Year-Olds by Kind of Exposure

Exposure	Yes		No		P Value
	No.	Score Above Cutoff, %	No.	Score Above Cutoff, %	
Severe damages at home	44	34.1	112	26.8	.37
Personal injuries	46	47.8	109	21.1	.001
Aftereffects	27	48.2	126	24.6	.01
Severely injured people in family	13	61.5	140	25.7	.006
Severely injured friends	40	42.5	109	22.0	.01

Table 6. Results of the Logistic Regression Among the 240 11- and 13-Year-Olds

Characteristic	Adjusted Odds Ratio (95% Confidence Interval)	P Value
Student in elementary school (vs junior high school)	1.8 (1.1-3.2)	.03
Girl	1.9 (1.1-3.2)	.03
Severe damages at home	1.9 (1.1-3.4)	.03
Personal injuries	2.6 (1.2-5.5)	.01

Table 7. Results of the Logistic Regression Among the 148 15- and 17-Year-Olds

Characteristic	Adjusted Odds Ratio (95% Confidence Interval)	P Value
Girl	8.3 (3.2-21.3)	<.001
17 years old	4.4 (1.8-11.1)	.002
Personal injuries	2.8 (1.1-7.0)	.02

with personal injuries only, and up to 72.7% among those with injuries both personally and in their families.

LOGISTIC REGRESSIONS

The results of the logistical regression models appear in **Table 6** for 11- and 13-year-olds (R-IES) and in **Table 7** for 15- and 17-year-olds (IES-R). Among the 11- and 13-year-old students, the girls enrolled in elementary schools with severe damage at home and personally injured were more likely to show SCW-PTSD. Among the 15- and 17-year-olds, being a girl, being aged 17 years, and being personally injured increased the likelihood of showing SCW-PTSD.

COMMENT

Nine months after the AZF explosion, 38.6% of directly exposed students still showed SCW-PTSD, contrary to empirical evidence that symptoms tend to attenuate over such a period.^{11,12} Eighteen months after the explosion, a related study conducted in a matched, economically disadvantaged suburb (comparable with that of the directly exposed group) of Toulouse among sixth graders (generally 11-year-olds) found 34.7% with SCW-PTSD in the proximal zone and 21.2% in a comparable distal zone. In comparison, the current study found 47.3% of directly exposed and 23.4% of nondirectly exposed 11-year-olds with SCW-PTSD after 9 months. Thus, SCW-PTSD in the 2 distal groups were almost identical at 9 and 18 months, but the SCW-PTSD appeared to have attenuated in the proximal groups. These results are consistent with other studies using the R-IES with children. For example, 52% of child survivors (aged 11-18 years)

of the sinking of the *Jupiter* showed SCW-PTSD 1 year after the event.¹³ Similarly, 37% of children (aged 2-15 years) exposed to the Buffalo Creek dam collapse were given a “probable” diagnosis of PTSD 2 years after the event.¹⁴ Not only were the Toulouse students exposed to the explosion, but they also had to cope with its consequences for months, in town, at school, and at home. The persistence of SCW-PTSD in both the 9- and 18-month follow-up studies of nondirectly exposed (or from distal zone) 11-year-olds at a 20% to 25% rate may represent a “baseline” level of SCW-PTSD, perhaps updated or escalated from an ongoing, post-AZF and September 11 barrage from proximal and distal threats, drawing on personal experience and the media.

In the 15- and 17-year age group, girls were more likely than boys to show SCW-PTSD when the exposure was controlled, 17-year-olds exceeded 15-year-olds, and those with personal injuries exceeded those without injuries—all findings consistent with most of the literature.¹⁵⁻¹⁷ Moreover, the effects of injuries were cumulative: students personally injured and with injured family members showed higher rates of SCW-PTSD than those experiencing either personal or family injury.

Our results suggest differences for 11- and 13-year-olds vs 15- and 17-year-olds; however, because we used 2 different scales (to accommodate age-group differences) and because 2 high schools were destroyed (perhaps elevating trauma disproportionately), conclusions about such age-group differences must be tentative.

An excess of SCW-PTSD of approximately 50% for the 11- and 13-year-olds and 75% for the 15-year-olds can be attributable to direct experience of the explosion. However, the very high prevalence of SCW-PTSD among nondirectly exposed students in the 11- and 13-year-old categories, but not in the 15-year-olds, raises questions about the tendency of younger students to overreport and about the validity and specificity of the

R-IES in French. Such screening tools should always be complemented by clinical interviews to assess PTSD more definitively. The temporal proximity between the AZF explosion in Toulouse and the terrorist attack on the World Trade Center only 10 days earlier should also be considered a contributing factor for elevated rates of SCW-PTSD, especially among nondirectly exposed students. Anecdotally, we have illustrated how children blurred the 2 events. Teachers reported that right after the explosion, children did not want to come out from under their desks, waiting for the second plane to crash or frightened of terrorists who would shoot them. As noted earlier, students asked to draw the AZF explosion as a classroom exercise showed planes flying into the AZF tower or showed 2 towers when in fact there was only 1. Similarly, many adults in Toulouse had difficulty relinquishing the belief that terrorists caused the explosion. Indeed, the catastrophes of September 11 were given full, prolonged media coverage in France, as was the AZF explosion, particularly in Midi-Pyrénées. Others have found that media exposure can lead to SCW-PTSD even among “nonexposed” children.^{18,19} In addition, the finding by others that PTSD levels are higher among those who already suffered from traumatic stress²⁰ could explain the high rates found in nondirectly exposed students.

Study results also served as a needs assessment and as such helped authorities plan and prioritize the allocation of resources to address the problem of continuing, elevated rates of SCW-PTSD, including funds for school doctors, social workers, and psychologists, with the intent of providing additional counseling for children screened positive for PTSD and depression.²¹ Our findings suggest that even a long time after a traumatic event, a substantial proportion of children are still likely to show psychological disorders and thus should have access to specific care. Some specific subpopulations (having injuries personally, showing aftereffects, having injured family members, living in a severely damaged home) are more vulnerable to PTSD. Students should be systematically screened and those with certain profiles given priority attention to avoid long-lasting effects.

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