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Concern About Petrochemical Health Risk Before and After a Refinery Explosion

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Abstract

On March 23, 2005, a large explosion at an oil refinery in Texas City, Texas caused 15 deaths and approximately 170 injuries. Little is known about how such an industrial accident influences concern about environmental health risks. We used measures of environmental health concern about nearby petrochemical production with a sample of Texas City residents to understand patterns of concern and change in concern after an industrial accident, as well as individual and contextual factors associated with those patterns. Survey interviews with residents of Texas City, Texas (N =315) both pre- and postexplosion using a brief Concern About Petrochemical Health Risk Scale (CAPHRS) and other questions were used to collect pertinent predictor information. CAPHRS baseline, postexplosion, and change scores were compared and modeled using ordinary least squares (OLS) regression and a mixed model. Higher preexplosion CAPHRS scores were predicted by younger adults, foreign-born Hispanics, non-Hispanic blacks, lower- and middle-income groups, and those who live with someone who has worked at the petrochemical plants. Higher CAPHRS change scores are predicted by the same variables (except income), as well as proximity to, or perception of, the explosion, and reports of neighborhood damage. Findings suggest these groups' concern scores could indicate a greater vulnerability to psychological and physical harm generated by concern and stress arising from local petrochemical activities. A clearer understanding of concern about actual environmental health risks in exposed populations may enhance the evolving theory of stress and coping and eventually enable public health professionals to develop appropriate mitigation strategies.

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Keywords

Concern; environmental health risk; petrochemical; stress; Texas City

1. INTRODUCTION

Among the types of human-environment relationships studied across scientific disciplines are those that entail environmental hazards. Whereas natural hazards (e.g., floods and earthquakes) usually pose a greater threat to human property than human health, technological hazards (e.g., nuclear waste repositories and chemical plants) typically contain a greater threat to health than to property. Uncertainty about how, to what extent, or when a hazard would damage health always exists, yet individuals in the United States and elsewhere perceive technological hazards as greater risks to health than natural hazards, and those respondents rank toxic waste sites and chemical manufacturing high on the lists of potential health risks.[(1–3)] The perceived risk associated with synthetic chemicals and their industrial production commonly translates into a generalized stress[(4)] or into more specific emotional responses such as a fear of cancer.[(5–7)] The study of environmental hazards should therefore be informed by theory and evidence about stress and risk perception.

The linkages between hazards, perceptions of risk, stress, and well-being are logical and supported by a synthetic view of evidence and theory. To understand stress and health effects of living with the technological form of environmental hazards, perceptions of risk specific to a local hazard become the logical and necessary starting point. It is noteworthy, however, that perceptions such as environmental health concerns, and particularly their change in response to adverse events, have been underresearched.[(8)] This study uses measures of environmental health concern about nearby petrochemical production with a sample of Texas City, Texas residents to understand patterns of concern and change in concern after an industrial accident, as well as individual and contextual factors associated with those patterns. Our intent was to examine how environmental health concern is related to ongoing industrial activity and an adverse event associated with that activity. The analysis allowed us to assess how the appraisal of a stressor is distributed across the landscape of a community under chronic exposure to risk and also to assess how the stressor is reappraised after an accident associated with the hazard. Furthermore, our data provided a view into the response to environmental hazards among foreign- and U.S.-born Hispanics, groups who have largely been left out of such research in the past. Such an evaluation, moreover, is useful for specifying how certain dynamics of the stress and coping process— appraisal in particular—are shaped by various contextual factors such as ethnicity, age, and exposure. The assessment of concern and its change within these circumstances and groups provides insight on stress and coping theory as well as the relative potential vulnerability and resilience within a population that is both chronically exposed to a technological hazard and acutely exposed to occasional accidents such as explosions.

2. BACKGROUND

Our study of a population exposed to a petrochemical hazard is informed by theory and empirical evidence. The theoretical basis is derived from a synthesis of stress and coping theory, and the risk perception literature. In our view, the synthesis of these literatures provides a useful composite view of how people transact with environmental hazards and are affected by those transactions. In this section, we first lay out theoretical and empirical evidence about environmental hazards and stress that pertain to our problem. Based on that body of work, it makes sense to consider the relatively more empirical insights from research on risk perception. In closing the section, we put the place and hazard of our study in context by a brief discussion of previous accidents and related research. This background informed our approach to the study and assists interpretation of our findings.

2.1. Environmental Hazards, Appraisal, and Stress

Environments offer a range of hazards that may act as stressors. While natural hazards continue to pose risks to human health and well-being, the real and perceived risks associated with technological hazards have increased dramatically during the last century, exceeding those associated with natural hazards. Experts from U.S. governmental offices, agencies, and scientific committees have called for a better understanding of how people respond to environmental health hazards.(9) Environmental hazards can be usefully theorized as stressors that can lead to stress responses and subsequent negative health outcomes in individuals. Lazarus and Folkman(10) set out a theoretical basis for the study of stress and coping that Lazarus(11,12) later updated.

Key components of Lazarus's theoretical argument are as follows. Person-environment relationships are unstable or changing. Instability implies an ongoing transaction in which people are affected by their environments through the changing relationships with them, and they are in turn attentive to, and sometimes affect, those environments. A potentially threatening environment (stressor) places a demand on potentially affected persons to appraise the threat. Lazarus(11) defines appraisal as the "continuing evaluation of the significance of what is happening for one's personal well-being." It is often overlooked that Lazarus's theory viewed appraisal as both cognitive and emotional in that the significance of a situation evokes an emotional response of anger, anxiety, or sadness. Primary appraisal includes the evaluation of the possible implications of a stressor, whereas secondary appraisal focuses on how a person is able to control or respond to the stressor. Both forms of appraisal in turn stimulate coping behaviors to adjust to the stressor. The coping part of the process is intended to reduce psychological and physiological stress on the individual, but coping may not be sufficiently effective, and stress-induced disease may eventually arise.(13)

The transactional theory of stress and coping, therefore, suggests that appraisal is the starting point for understanding stress and its sequelae in human populations. It also argues for repeated measures of appraisal to better understand dimensions of the coping and stress process. Appraisal is viewed by Lazarus(11) as both an ongoing process (state) that includes reappraisals of threats, as well as a style (trait). As a process, appraisal will fluctuate with changes in the person, environment, and the person-environment relationship. Social context and individual characteristics may modify the stress process by shaping both exposure to stressors and resources for the stressed individual to use in response.(14,15)

From the transactional theory of stress and coping, we can begin to understand how environmental health hazards and appraisal of them may generate an emotional response. The typical emotional response is anxiety related to the "ambiguity" and "uncertainty" entailed in such "existential threats" to personal well-being.[(11)] Hallman and Wandersman[(4)] add to this by suggesting that the perceived risk of environmental threats translates into psychological distress for exposed populations because of fear of potential health problems, the uncertainty of the threat, lack of control, actions of others perceived to cause the threat or reacting against it, and stigmatization. Although the study of human response to technological hazards continues to develop, research to date supports Hallman and Wandersman's claim. Most studies in this area have been conducted on toxic waste sites—where researchers uniformly find psychosocial distress among nearby residents[(16–22)]. Psychosocial anxiety and distress often translate into physiological stress with a wide range of effects on health and well-being.[(23)]

Active industrial sites, particularly those producing petrochemical products, are associated with increased stress and self-reported illness. Burby and colleagues'[(24,25)] investigation of populations in the petrochemical corridor in Louisiana discovered associations between risk perception and stress. Using quantitative and qualitative methods, Luginaah and colleagues[(26–28)] reported similar findings in a predominantly non-Hispanic white population living around a single petroleum refinery in Ontario, Canada. Focusing on odors as the primary signal of risk, that research found a stress response to refinery emissions. Not only did survey respondents tend to make a connection between odors and health effects, but analyses revealed significantly increased odds of reporting more illness symptoms for those who also reported refinery odor perception or odor annoyance. Residents living near the refinery also displayed increased action- and emotion-focused coping behaviors in response to their concerns.

The transactional theory of stress and coping is a logical and supported view of the relationship between environmental hazards and the human response to them. Consideration of social factors and geographical contexts is an important extension of the theory. In addition, the dimension of appraisal is, unfortunately, frequently overlooked to a significant extent in stress research—it is one of the less frequently studied and understood components of the theory. Measurement of stressor perception is generally implied and taken for granted in research that does not have an environmental component, such as disease diagnosis, for example. The appraisal of risk in populations exposed to environmental hazards is an essential first step in understanding stress and wellbeing in such situations.

2.2. Risk Perception

The risk perception literature provides the most direct view into the nature of environmental health concern and factors associated with it. Risk perceptions are the subjective evaluations —the effective appraisal—of a hazard. The understanding of risk perception derives from the work of geographers, sociologists, psychologists, anthropologists, and political scientists.[(29)] Appraisal processes can be complex in response to natural or technological hazards. The risk perception literature suggests that appraisal is shaped by individual and group differences, the nature of a hazard, and people's relationship to hazards. Risk perception also is increasingly viewed as part of larger social, cultural, and political processes.

Early studies used a psychometric paradigm to explore risk as it was perceived by the general population. The goal was to understand the components and characteristics of hazards that contributed to risk perception. In that view, individuals assess and assign natural and technological hazards a subjective level of risk regardless of true threat.[30] In studies focused on a distinctly cognitive, rational basis of risk perception, hazards perceived as exhibiting lower risk are usually those assessed to be natural, detectable, equitably distributed, scientifically understandable, somewhat controllable, familiar, or of less threat to human life.[9,30,31]

Much of the work on risk perception has attempted to understand how groups differ on their perceptions of generalized (nonlocal, nonexperienced) risks. Findings from these studies showed considerable variation in the perception of risk associated with specific activities and technologies[29,30] In particular, age and gender have been associated with differences in the perception of environmental health risks. Several studies reported that women perceived risks as greater than do men given similar scenarios.[32–36] There is limited research reporting on the effect of age, but younger people have been found to express more worry about hazards.[35] In addition, different socioeconomic communities in the same city rate the risks of various hazards differently.[37]

In contrast to the psychometric focus on individual trait or state factors that might affect risk perception, a more recent approach incorporates broader contextual factors of a socioeconomic or cultural nature to explain risk perception. Racial and ethnic minorities in the United States exhibit greater perceived risk than non-Hispanic whites when rating various abstract or real environmental health hazards.[2,24,25,38,39] Some findings suggest that intergroup variation is based more in sociopolitical differences among groups than on race or ethnicity, with lower-status groups perceiving greater risk levels.[1,37] Minority groups may perceive greater industrial-related health risks because they have more experience with exposure, feel more vulnerable, and view such risks as a form of injustice[24,40–42]. Thus, group affiliation, in addition to individual differences, is viewed as an important dimension of risk perception.

Geographical contexts of exposure are additional, important risk perception factors. The roles of place (e.g., neighborhood) are important in the process of technological hazard risk perception and psychosocial effects.[17,18] Proximity to a threat, neighborhood setting, attachment to place, sense of community, and economic ties to the industry involved in a hazard also can alter risk perception.[24,43,44] It appears that individual characteristics, group membership and socioeconomic status, and exposure context are intertwined in the perception of risk.

The nature of a hazard and a person's relationship to it also are important. In large studies of risk perception, respondents rate chemical pollution and chemical manufacturing as greater public health risks than most other types of threats.[1,2] In addition, risks that are viewed as industrial, involuntary, uncontrollable, and unfair are perceived as greater in magnitude than their opposites.[9,37] Media and action groups also can modify risk perception through social amplification.[45] Risk perception theory is evolving to explain such findings. Of note is the work by Slovic and colleagues who suggest dual processes informing risk perception: a cognitive, rational process and an intuitive, emotional process.[46] This recent work mirrors the evolution of Lazarus's position on appraisal and moves the field toward a more intricate understanding of risk perception.

2.3. Texas City's Petrochemical Hazard in Context

Petrochemical processing activity is concentrated in large clusters of refineries and associated plants across the Gulf Coast in Texas and Louisiana. One of the largest clusters resides in the Texas City Industrial Complex approximately 45 miles southeast of Houston. The complex covers approximately eight square miles and contains intensive processing activity located in close proximity to residential areas in the city. Many residents are aware that the petrochemical industry is a hazard that poses some level of risk to their health. The 1947 disaster that killed approximately 600 residents is memorialized in the city and later accidents that harmed people working at the plants or living nearby are widely recalled by the community.

One accident was a significant hydrogen fluoride spill in 1987. A large-scale epidemiological study (10,000+ sample) of the after-effects of that spill in Texas City suggested that health problems related to the petrochemical industries existed before the spill.[47,48] Exposure to hydrogen fluoride in the neighborhoods nearer to the complex was manifested in health symptoms for at least two years after the spill. In addition, psychological stress was linearly related to exposure. Moreover, perceptions of exposure were discovered to be as important as direct exposure itself in predicting reported health effects. Women exhibited a higher sensitivity to risk (rating it as higher) than men, and both genders put much of the blame on industry and government for the spill and health effects. Although most of the physical effects of the spill likely have long since dissipated, Dayal and colleagues' research serves as an important prelude to the analysis presented here. It offers evidence that the risks entailed in living near petrochemical industries is both real and perceived by residents; Texas City is not an exceptional case as far as petrochemical production and risk is concerned. Dayal's study, like almost all studies before and after it, however, did not have access to measures of concern about environmental health hazards before and after an adverse event.

On March 23, 2005, a large explosion at an oil refinery in Texas City caused 15 deaths and approximately 170 injuries. The blast blew out windows in nearby neighborhoods and shook buildings 10 miles away. Smoke plumes from the resulting fires could be seen for at least 10 miles and the event was covered intensively in the local media. Although initial news reports implied no threat to the Texas City community from chemical releases as a result of the explosion and fires, 10 months later (after our data were collected) reports appeared that tens of thousands of pounds of hazardous chemicals were released into the atmosphere subsequent to the blast, including benzene, heptane, and hexane.[49,50] At the time of the explosion, a social epidemiology study focusing on stress and health was collecting data from a sample of approximately 35,000 residents living within a 12-square-mile area bordering the large petrochemical complex in Texas City. Researchers returned to study the effects of the blast on concerns about health risks posed by the petrochemical plants, that is, the concern resulting from appraisal and reappraisal of the existential threat to health associated with the plants.

The explosion created the opportunity for a natural experiment whereby change in concern could be examined to assess (1) patterns of concern existing in the sample preexplosion; (2) patterns of change in concern from pre- to postexplosion; and (3) what factors were associated with concern and its change. Our analysis provides new information about how a significant industrial accident changes concern, and how that change is associated with numerous factors of interest. The data allow us to assess these patterns and changes within a population that has experienced such accidents and concerns over decades. Knowledge of such change suggests differential vulnerabilities that are not apparent when investigating risk perceptions in a purely cross-sectional manner, and they allow us to speak to the transactional theory of stress and coping and the central ideas in risk perception.

3. DATA AND METHODS

3.1. Participants and Data Collection

The study's primary aims were to examine the social, psychological, behavioral, and biologic factors related to stress and health in that multiethnic (Hispanic, non-Hispanic black, and non-Hispanic white) population. In July 2004, the project began using a multistage probability sample plan to select potential participants. The first stage included selection of three ethnic strata: Mexican Americans aged 25–64, Mexican Americans aged 65 and over, and non-Hispanics. The second stage involved the selection of housing units (HUs) in each stratum. In this stage all Hispanic HUs and one in eight non-Hispanic HUs were selected. The third stage included selecting one adult per household among Mexican Americans aged 25– 64 and among non-Hispanics. All Mexican Americans aged 65 and over were selected.

Participant eligibility criteria included: 25 years of age or older, currently living in the study area, and informed consent. Trained interviewers administered an approximately hour-long, in-home interview that collected perceived health status, a range of psychosocial factors, health behaviors, demographic variables, and concerns regarding the health risks of the petrochemical plants. Using the enumeration rate of all housing units (83%) and the survey rate for all selected participants (84%), the total response rate for the interviews to the time of the explosion was 70% (the cross-product of enumeration and survey rates).

The explosion prompted the research team to administer an additional, postexplosion survey. At the time of the explosion, 550 participants had completed interviews. These participants had been not only randomly chosen based on the multistage design, but also were geographically randomized by neighborhood to create variation in exposure in case of an adverse event at the petrochemical facilities. The geographical randomization also resulted in good variation in the sample by predictor subgroups, such as race/ethnic groups, who tend to cluster in urban space. Of the 550 preexplosion participants, 57% (n = 315) agreed to be reinterviewed after the explosion via a 30-minutelong telephone survey (106 of the 315 postexplosion respondents, unreachable by telephone, completed a postexplosion face-to-face interview). Preexplosion concern scores did not differ between those consenting to the postexplosion survey and those refusing participation ($p = 0.36$). More men than women consented to the postexplosion survey ($p = 0.003$). Time between the two surveys ranged from 1 to 13 months (mean = 6.2, $SD = 2.8$), with the last postexplosion survey completed on August 31, 2005. Both the baseline and postexplosion studies were approved by the Institutional Review Board (IRB) at the University of Texas Medical Branch. The analyses reported in this article also have IRB approval through the University of North Carolina at Chapel Hill.

3.2. Outcome Measure: Concern About Health Risks of Petrochemical Plants

The "Concern About Petrochemical Health Risk Scale" (CAPHRS) was created by the first and third authors specifically to measure individual concern about the nearby petrochemical plant's potential to harm personal or family health. The scale was translated into Spanish by a native speaker and back-translated by another native speaker to ensure fidelity to the English instrument. It was pilot tested with 334 Hispanic, non-Hispanic white, and African-American residents of another coastal Texas community with numerous refineries. The original scale included 12 items, and exploratory and confirmatory factor analysis results suggested that the scale could be streamlined to the final four items used in the Texas City study. Specifically, the exploratory work showed two highly redundant six-item factors, correlated 0.87. A confirmatory model showed acceptable fit for a second-order model, but only after gross re-specification: 15 pairs of error scores were allowed to correlate. The correlated errors, evidently owing to response set across highly similar items, also implied item redundancy. Therefore, the items were trimmed and consolidated to a final four items for the Texas City project (e.g., three separate items about air, soil, and water pollution were combined into a single "pollution" item). The final four-item scale included concern about the health risk from pollution (air, soil, and water), accidents (explosions, toxic spills), stored waste, and the health risk in general from nearby oil and chemical industries (see the Appendix). The five-point response scale provides a total scale score ranging from 5 to 20 with higher CAPHRS scores indicating a greater concern. In this study sample, the scale also has good reliability ($\alpha = 0.96$), and that a high degree of internal consistency is consistent for foreign-born Hispanics ($\alpha = 0.93$), U.S.-born Hispanics ($\alpha = 0.96$), non-Hispanic blacks ($\alpha = 0.90$) and non-Hispanic whites ($\alpha = 0.96$). Change in CAPHRS scores was calculated by taking the raw difference in the total scale scores from pre- and postexplosion interviews. Confirmatory factor analysis of the preexplosion CAPHRS data suggested good unidimensional model fit with the comparative fit index at 0.97, and the root mean square error of approximation at 0.059 (90% CI = 0.046–0.072). This result implies a one-dimensional structure that measures concern of the specific health risk. Discriminant validity evidence for the scales was provided by correlations with two other scales in the study. Theoretically, efficacy beliefs about coping with environmental hazards should be independent of concern about health risks of such hazards. A structural equation measurement model showed that the two latent variables of concern and self-efficacy were unassociated, with $r = -0.04$ ($p = 0.59$). Collective efficacy and concern were also unrelated ($r = 0.12$, $p = 0.08$) suggesting that CAPHRS data provide a straightforward, reliable, and valid measure of concern of health risk.

3.3. Individual and Sociocultural Predictor Variables

A set of relevant characteristics that pertain to individual and sociocultural dimensions of risk perceptions were collected at baseline: age, gender, race/ethnicity, education, income, and health insurance status. Based on analysis of its distribution in the sample, age, calculated using date of birth and date of baseline interview, was grouped into 3 categories: 25 to 44, 45 to 64, and 65 and older. Self-reported race, ethnicity, and birthplace responses were combined and coded as non-Hispanic white, non-Hispanic black, U.S.-born Hispanic, and foreign-born Hispanic. We separated native and immigrant Hispanics because the literature on Hispanic health indicates significant differences between the two groups.[(51–53)] Education was assessed as self-reported highest grade of school completed, and analyzed as ordinal categories: less than high school, high school graduate, some college, and college graduate or greater. Annual household income was assessed with four ordinal categories: < $10,000 to $14,999, $15,000 to $24,999, $25,000 to $49,999, and $50,000 or more. Health insurance status, a variable that theoretically could influence perception of health risk, did not distinguish between private and public health insurance, and was coded as currently had or did not have insurance. Perceived control over the hazard was assessed both pre-and postexplosion with a single question, “How much control over the potential risks associated with the oil and chemical plants do you think you have?” and analyzed as ordinal categories: no control at all, a little control, some control, and total control.

3.4. Exposure Predictor Variables

Based on its multimodal distribution in the sample, years of residency in Texas City was coded as less than or equal to 15 years, 15–30 years, and greater than 30 years. Researchers assessed preexplosion petrochemical plant work with two questions:“Who in your household is currently working at a petrochemical plant?” and“Who in your household has ever worked at a petrochemical plant?” Response categories were self, family member, other household member, and no one. The petrochemical work variable combined the two questions into a dichotomous variable: either the respondent, a family member, and/or another household member currently or previously worked at a petrochemical plant, or no one in household had ever worked in a petrochemical plant. Researchers used geographic information system analysis to calculate the distance in miles for each respondent’s household from the explosion site; values ranged from half a mile to just over three miles. The distribution of distance in the sample suggested a dichotomization into “living closer than 1.5 miles to explosion site” versus “living further than 1.5 miles.” On the basis of three questions asked in the postexplosion interview, respondents were assigned an impact score of “yes” if they had heard, seen, or felt the explosion, and “no” if they had not responded yes to any of the conditions. Perceived damage to the neighborhood was assessed in the postexplosion interview with the question: “Was there any property damage to your neighborhood due to the explosion?”

3.5. Analyses

Baseline, postexplosion, and change in CAPHRS scores were used in analyses. Descriptive analyses show the patterns in CAPHRS scores and by subgroups (predictor variables). An ordinary least squares (OLS) regression with subgroups dummy coded was used to model baseline CAPHRS scores. A linear mixed model was run to assess subgroup effects on the CAPHRS change scores. A mixed model approach was used to account for the random effect of time in the follow-up survey methodology. Potential confounders, the time between the explosion and the follow-up survey, and the time between explosion and the postexplosion survey, were included as covariates in the mixed model. The mixed model also included the effects of explosion exposure variables (distance to explosion, explosion impact score, and damage to neighborhood). Analyses were carried out using SPSS v 14 and SAS v. 9.13 using a significance level of $\alpha = 0.05$. CAPHRS scores and change scores, *b*-weights (unstandardized regression coefficients), standard deviations, *t*-values, and *p*-values are reported in Tables II and III.

4. RESULTS

4.1. Study Participants

Sample characteristics are presented in Table I. Of the 315 participants, a majority (78%) were less than 65 years old, with the less-than-65 group being equally split into younger (25–44) and middle-aged (45–64). Two hundred and two (64%) were women. Hispanics were the largest racial/ethnic group (65%). More than half of the sample had a high school education or more (58%), and a similar proportion had a total household income less than $25,000 a year (54%). Just over half of the sample reported having health insurance (54%). Nearly one-third (32%) of participants had lived in Texas City for 31 years or more, and almost half (47%) reported a household member who worked or had worked in the local petrochemical industry. A majority of participants (61%) perceived that they had no control over the risks associated with the petrochemical plants. Most participants lived 1.5 miles or further from the explosion site (68%) and did not have explosion damage in their neighborhoods (72%); however, a majority (72%) heard, felt, and saw the explosion.

4.2. Concern Preexplosion, Postexplosion, and Change by Group

Although the overall sample’s means on pre- and postexplosion CAPHRS scores are not statistically different, the patterns shown in Table I are suggestive of group differences in concern scores and change in concern. Subgroups within the sample—the older, male, non-Hispanic whites, U.S.-born Hispanics, college educated, insured respondents, and those perceiving no control over the hazard at baseline—rated their concern lower in both the preexplosion and postexplosion survey. Those individuals without a household member with petrochemical work experience also exhibited less concern at both interviews. A pattern with higher income and higher education groups showing less concern becomes clearer in the postexplosion responses. Those living longest in Texas City expressed less concern about health risks at follow-up. The change scores calculated from the pre- and postexplosion CAPHRS scores are also telling. While the male-female and petrochemical work exposure gaps tighten from pre to post, the change scores indicate a widening of differences by age, racial/ethnic, education, income, and health insurance subgroups. A similar divergence is apparent in the years in Texas City subgroups and in the perceived control of risk hazard subgroups. There is not much change in the distance and impact groups’ scores. The gap between petrochemical-work groups’ concern narrows and the damage to neighborhood groups’ difference widens.

4.3. Models Predicting CAPHRS Scores and Change in Scores

The first model assesses the association between preexplosion CAPHRS scores and the set of predictors. Any subgroup without coefficient and statistical test information (Table II) is the reference group. The overall model was significant ($F = 5.00$, $p \leq 0.001$), with an $R^2 = 0.134$ that indicates a medium effect size (Cohen's $f^2 = 0.155$). In this model, statistically significant associations with higher preexplosion CAPHRS scores were exhibited by younger adults ($b = 2.565$, $p < 0.001$), females ($b = 0.903$, $p = 0.024$), foreign-born Hispanics ($b = 1.901$, $p = 0.002$), non-Hispanic blacks (b=2.045, p=0.004), the lowest income group ($b = 1.416$, $p = 0.005$), the second highest income group ($b = 2.120$, $p < 0.001$), and those in households with petrochemical industry ties ($b = 1.663$, $p = 0.001$).

The mixed model assesses the predictors' association with the change in CAPHRS scores from the preexplosion survey to the postexplosion survey (Table III). This model includes fixed and random time effects. Younger and middle-aged adults ($b = 2.655$, $p = 0.001$; $b = 1.569$, $p < 0.045$), foreign-born Hispanics ($b = 2.009$, $p = 0.024$), non-Hispanic blacks (b=2.691, p=0.011), those in households with petrochemical industry ties ($b = 1.351$, $p = 0.018$), those closer to the explosion site ($b = 1.399$, $p = 0.033$), those with high explosion impact scores ($b = 1.290$, $p < 0.041$), and those reporting damage in the neighborhood ($b = 1.332$, $p = 0.038$) were statistically significant predictors of higher CAPHRS change scores. Time variables showed no relationship with change scores.

5. DISCUSSION AND CONCLUSION

We examined patterns of concern about petrochemical health risk using a unique pre- and postexplosion data set. In addition, we have taken the opportunity to assess the association of several personal and contextual variables with concern and its change in response to the explosion and fire at a Texas City petrochemical refinery. Regression analysis of preexplosion CAPHRS scores (Table II) reveals the cross-sectional pattern of concern about environmental health risks posed by the petrochemical plants in Texas City. That pattern is shaped by various individual, socioeconomic, and exposure factors.

The regression results correspond with previous research findings that ethnic minorities and younger adults show greater concern with environmental health risks.[2,24,25,35,38,39] Our regression findings diverged from previous studies that discovered women to be more concerned, or to perceive more risk, than men. We note, however, Baxter and Lee's[54] observation of "latent concern" in women or other groups that exists as a potential stressor but may not be expressed in responses to an instrument such as the CAPHRS. The significant effect of petrochemical work on concern about petrochemical health risk was unexpected. A plausible explanation for increased concern in those living in households with petrochemical plant work experience is that occupational risk exacerbates environmental health risk concerns. Rather than becoming habituated to the environmental health risks, respondents in households who are or have been economically tied to the plants may have a greater understanding of plant complexity, dangers, and chemical risks involved.

Perhaps the most remarkable part of the results is the mixed model derived for CAPHRS change pre to postexplosion. Although Table I reveals no significant pre-to postexplosion change in the overall sample, there are significant changes in a few subgroups. And even though the significant predictors in the OLS and mixed models do not exhibit extremely large effect sizes, the inclusion of many covariates in the model predicts effects that are more conservative estimates than if we had used less-specific models. In essence, inclusion of a large set of covariates partitions effects into a number of different predictors. The pattern of statistically significant predictors of increased concern (Table III) is consistent with pre-explosion pattern as far as age, race/ethnic subgroups, and petrochemical work is concerned. Income group associations with concern exhibited in the OLS analysis of preexplosion concern disappear with inclusion of additional exposure variables in the mixed model. We hypothesize that because less-expensive (lower-income) housing is most frequently located nearer to the petrochemical facilities where the explosion took place, the exposure variables are confounded with the lower-income group's effect. The middleclass association also disappears, and these contrary results could be an artifact of information loss inherent in income categorization.(55) Orit could be that the significant effect in the preexplosion model was simply a type I error resulting from multiple significance tests.

It is a potentially important finding that younger, foreign-born Hispanics, and non-Hispanic black groups were more concerned with environmental health risk from the plants preexplosion *and* exhibited a greater upward shift in concern after the explosion in Texas City. Concern was both elevated within these groups, and was more exacerbated by the adverse event. These findings suggest a greater vulnerability to psychological or physical harm related to concern with petrochemical activities in their community because those concerns are independent of exposure to the explosion or to petrochemical work. This is supported by correlations of CAPHRS scores and self-reported health scores collected with the SF-36. Blacks' CAPHRS scores are associated with poorer physical health scores ($r = -0.40$, $p = 0.03$), and foreign-born Hispanics' CAPHRS scores are associated with worse mental health scores ($r = -0.22$, $p < 0.001$). Conversely, our data depict older, U.S.-born Hispanics, non-Hispanic whites, and those less exposed to the industries as less concerned and potentially more resilient.

As the risk perception literature has rediscovered, concerns about environmental health risks may be heavily influenced by cultural context, group identity, and the social environment. The cultural theory of risk(56) and the social network contagion theory of risk perception(57) may help explain how individuals understand, rationalize, and become concerned about ongoing risks and occasional accidents. Both theories suggest that the more tightly networked individuals are, the more likely they are to share information, attitudes, and beliefs within their social network, and adopt a less individualistic and more collective understanding of risk.(57,58) Both theories could be used to explain why foreign-born Hispanics and non-Hispanic blacks report more concern about their local environmental health risks. From what we know of Texas City through our experience there, members of these two groups are more likely to interact more with members of their group than with those of other groups. Adding to those explanations is the role that discrimination and justice perceptions play in increasing risk perception and concern.(42) It is plausible that self-perceived marginalization of foreign-born Hispanics and non-Hispanic blacks in Texas City exacerbates concerns about environmental health risks of group members. Another societal-level explanation for the foreign-born Hispanic response is the role of lower environmental awareness. In a multicountry sample, Lima and colleagues[59] discovered that environmental awareness mediated the relationship between societal technological development and risk perception. It is plausible that immigrants from less technologically developed societies, such as Mexico, would have less environmental awareness and thus greater perceived petrochemical risk both before and after an explosion.

The findings presented in this article are even more sensible when considered in the context of transactional stress and coping theory. While the analysis was not conducted as a test of Lazarus's theory, it serves to offer support for his nuanced relational view of appraisal of environmental threats. The finding that exposure variables, such as petrochemical work, distance from the plants, and neighborhood damage, are related to increased concern after the explosion provides a good case study of how appraisal is sensitive to variation in the person-environment relationship. Moreover, the idea of appraisal as an ongoing process is evident from changes in appraisal in response to the explosion. Yet, our results also suggest that appraisal styles are at work in our sample. Both the pre- and postexplosion concern of those in the most marginalized ethnic groups (foreign-born Hispanics and non-Hispanic blacks) could indicate a different style, or trait, of appraisal of the petrochemical plant threat to health. Whereas non-Hispanic whites and U.S.-born Hispanics displayed less concern after the explosion, the other two groups appeared less secure about the risk of the plants and how it might influence their health. To the best of our knowledge, this type of evidence for Lazarus's theory of stress and coping is unique.

A few limitations of our analyses should be noted. Because of the nature of the environmental health hazard, the residential context, and the CAPHRS scale that was specifically designed for this study, the results may not readily generalize to other populations. Although the participation rate for being reinterviewed postexplosion was only 57%, we believe that the rate is acceptable given the unusual circumstances. While preexplosion concern scores were similar for consenters and nonconsenters of the postexplosion survey, we could not assess whether those two groups' postexplosion concern was also similar. Finally, information about the presence of children in the household of respondents might have enhanced insight into concern and its change, but we did not have those data for use in the models.

Environmental health hazards threaten the physical and mental health of exposed populations. We and others have hypothesized that concern about such hazards may lead to negative health consequences that are perhaps as important as direct physical harm from such hazards. If this is correct, our findings imply that, in addition to the more commonly investigated issue of toxic exposure, concern about environmental health risk is a health disparities issue. Concern about environmental health risks associated with a nearby petrochemical complex appears to be different for the young and the more disadvantaged racial/ethnic minorities as well as for those with greater exposure to the industries through work and residential location. As the study of risk perception and concern about environmental hazards continues to evolve, special attention to these factors should yield a more refined understanding of how environmental health threats influence mental and physical health/well-being. A clearer understanding of concern about actual environmental health risks in exposed populations may enhance the evolving theory of stress and coping and eventually enable medical and public health professionals to develop appropriate mitigation strategies for groups that most need them.

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APPENDIX: CONCERN ABOUT PETROCHEMICAL HEALTH RISK SCALE (CAPHRS)

Question	Response	
1. How concerned are you that pollution from the oil and chemical plants might harm your health or your family's health?	**1**	Not at all concerned
	2	A little concerned
	3	Moderately concerned
	4	Very concerned
	5	Extremely concerned
2. How concerned are you that accidents, such as explosions or spills, from the oil and chemical plants might harm your health or your family's health?	**1**	Not at all concerned
	2	A little concerned
	3	Moderately concerned
	4	Very concerned
	5	Extremely concerned
3. How concerned are you that stored waste from the oil and chemical plants might harm your health or your family's health?	**1**	Not at all concerned
	2	A little concerned
	3	Moderately concerned
	4	Very concerned
	5	Extremely concerned
4. How concerned are you that the oil and chemical plants might cause health problems or disease in you or your family?	**1**	Not at all concerned
	2	A little concerned
	3	Moderately concerned
	4	Very concerned
	5	Extremely concerned

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Table I

Preexplosion, Postexplosion, and Change in Concern About Petrochemical Health Risk Scale Scores by Group

	N = 315[a]	Baseline CAPHRS Mean (*SD*)	Postexplosion CAPHRS Mean (*SD*)	Change CAPHRS Mean (*SD*)
Total sample	314	10.68 (4.8)	10.59 (4.8)	−0.09 (4.6)
Personal characteristics				
Age				
25–44	119	11.44 (4.7)	11.51 (4.4)	0.04 (4.7)
45–64	119	10.80 (4.7)	11.02 (4.7)	0.22 (4.4)
65 and older	68	9.06 (5.1)	8.50 (5.4)	−0.56 (4.8)
Gender				
Female	202	11.01 (4.7)	10.73 (4.7)	−0.28 (4.9)
Male	111	10.08 (5.1)	10.32 (4.8)	0.24 (3.9)
Race/ethnicity				
Foreign-born Hispanic	78	11.67 (5.1)	11.99 (4.2)	0.32 (4.8)
U.S.-born Hispanic	123	10.53 (4.9)	10.16 (4.9)	−0.37 (5.0)
Non-Hispanic black	30	11.97 (3.2)	12.80 (3.6)	0.83 (4.1)
Non-Hispanic white	80	9.40 (4.9)	8.96 (4.8)	−0.44 (4.0)
Education				
Less than high school	131	10.77 (5.2)	10.91 (4.8)	0.16 (5.1)
High school	100	10.74 (4.7)	10.81 (4.8)	0.07 (4.1)
Some college	53	11.17 (4.3)	10.32 (4.6)	−0.85 (4.2)
College	26	8.92 (4.8)	8.50 (4.5)	−0.42 (4.9)
Income				
<10,000 to 14,999	88	11.17 (4.4)	11.68 (4.5)	0.51 (4.7)
15,000 to 24,999	67	10.74 (4.9)	10.72 (4.6)	−0.02 (5.3)
25,000 to 49999*	74	11.19 (5.0)	10.34 (4.6)	−0.85 (3.9)
50,000+	46	10.27 (4.9)	9.80 (4.9)	−0.47 (3.8)
Health insurance status				
Not insured	144	11.12 (4.9)	11.65 (4.4)	0.53 (4.5)
Insured	171	10.33 (4.8)	9.70 (4.9)	−0.63 (4.6)
Perceived hazard control				
No control	218	10.92 (4.9)	10.56 (4.8)	−0.36 (4.6)
A little control	50	9.78 (4.6)	10.18 (4.4)	0.40 (4.3)
Some control	27	10.78 (4.2)	11.30 (4.9)	0.48 (4.5)
Total control	10	11.50 (5.2)	12.50 (4.3)	1.00 (5.8)
Exposure characteristics				
Years lived in Texas city				
<=15	130	10.35 (4.8)	10.89 (4.6)	0.54 (4.6)
15–30	78	11.02 (4.6)	11.06 (4.4)	0.04 (4.5)
31+*	102	10.86 (5.1)	9.79 (5.2)	−1.07 (4.6)

	$N = 315^a$	Baseline CAPHRS Mean (*SD*)	Postexplosion CAPHRS Mean (*SD*)	Change CAPHRS Mean (*SD*)
Petrochemical work				
Yes	141	11.43 (4.8)	10.76 (4.6)	−0.67 (4.1)
No	159	10.11 (4.9)	10.43 (4.9)	0.32 (4.9)
Distance to explosion site[b]				
<1.5 miles	96	12.14 (4.9)	12.07 (4.4)	−0.07 (4.3)
>=1.5	213	10.14 (4.6)	10.00 (4.7)	−0.14 (4.7)
Explosion impact score[b]				
High	226	11.20 (4.6)	11.04 (4.7)	−0.06 (4.5)
Low	87	9.30 (5.3)	9.36 (4.8)	0.06 (4.9)
Damage to neighborhood[b]				
Yes*	83	11.51 (4.9)	12.72 (4.0)	1.21 (4.6)
No	211	10.08 (4.8)	9.65 (4.7)	−0.43 (4.6)

[a]Subgroups do not always sum to 315 because of missing data.

[b]Exposure characteristics assessed postexplosion.

*Change is statistically significant at $p \leq 0.05$.

Note: CAPHRS scores range from 5 to 20, with higher values indicating stronger concern.

Table II

OLS Regression Model of Preexplosion Concern About Petrochemical Health Risk Scale (CAPHRS) Scores[a]

	b (SE)	*t*-value	*p*-value
Intercept	6.314 (1.1)	5.78	<0.001
Personal characteristics			
Age			
25–44*	2.565 (0.6)	4.51	<0.001
45–64*	1.959 (0.5)	3.81	<0.001
65 and older			
Gender			
Female*	0.903 (0.4)	2.27	0.024
Male			
Race/ethnicity			
Foreign-born Hispanic*	1.901 (0.6)	3.16	0.002
U.S.-born Hispanic	0.417 (0.5)	0.85	0.396
Non-Hispanic black*	2.045 (0.7)	2.88	0.004
Non-Hispanic white			
Education			
Less than high school	0.381 (0.7)	0.55	0.584
High school	0.207 (0.7)	0.30	0.765
Some college	0.999 (0.8)	1.32	0.187
College			
Income			
<10,000 to 14999*	1.416 (0.5)	2.80	0.005
15,000 to 24,999	0.787 (0.5)	1.45	0.149
25,000 to 49999*	2.120 (0.6)	3.47	<0.001
50,000+			
Health insurance status			
Not insured	−0.451 (0.4)	−1.02	0.308
Insured			
Perceived hazard control			
No control	0.324 (0.8)	0.41	0.681
A little control	−0.647 (0.9)	−0.73	0.467
Some control	0.494 (1.0)	0.50	0.618
Total control			
Exposure characteristics			
Years lived in Texas City			
<= 15*	−1.359 (0.5)	−2.78	0.006
15—30	−0.404 (0.5)	−0.78	0.438
31+			
Petrochemical work			

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	***b* (SE)**	***t*-value**	***p*-value**
Yes*	1.663 (0.4)	4.26	<0.001
No			
$F = 5.00$, $p = <0.001$			
$R^2 = 0.134$			

[a]All variables assessed at baseline.

*Group effect is statistically significant at $p \leq 0.05$.

Table III

Mixed Model of Change in CAPHRS Scores

	b (SE)	*t*-value	*p*-value
Intercept	3.913 (1.8)	2.15	0.033
Time (random effect)	−0.108 (0.3)	−0.35	0.727
Days from explosion	0.139 (0.1)	1.32	0.187
Time in months from preexplosion to postexplosion survey	−0.313 (0.4)	−0.79	0.428
Personal characteristics			
Age			
25–44*	2.655 (0.8)	3.24	0.001
45–64*	1.569 (0.8)	2.01	0.045
Gender			
Female	0.023 (0.6)	0.04	0.968
Race/ethnicity			
Foreign-born Hispanic*	2.009 (0.9)	2.28	0.024
U.S.-born Hispanic	0.676 (0.7)	0.98	0.326
Non-Hispanic black*	2.691 (1.1)	2.55	0.011
Education			
Less than high school	0.105 (1.1)	0.10	0.921
High school	0.327 (1.0)	0.32	0.751
Some college	0.510 (1.1)	0.46	0.643
Income			
<10,000 to 14,999	0.560 (0.8)	0.70	0.484
15,000 to 24,999	−0.367 (0.8)	−0.45	0.654
25,000 to 49,999	0.206 (0.9)	0.24	0.814
Health insurance status			
Not insured	−0.116 (0.7)	−0.18	0.859
Perceived hazard control			
No control	1.954 (1.2)	1.57	0.119
A little control	0.210 (1.3)	0.16	0.872
Some control	2.035 (1.5)	1.40	0.164
Exposure characteristics			
Years lived in Texas City			
<= 15	−0.342 (0.7)	−0.47	0.638
15–30	0.142 (0.8)	0.18	0.854
Petrochemical work			
Yes*	1.351 (0.6)	2.39	0.018
Distance to explosion site[a]			
<1.5 miles*	1.399 (0.7)	2.14	0.033
Explosion impact score[a]			

	***b* (SE)**	***t*-value**	***p*-value**
High*	1.290 (0.6)	2.06	0.041
Damage to neighborhood[a]			
Yes*	1.332 (0.6)	2.09	0.038
Random effect parameter estimates			
Intercept	9.18 (1.54)		
Residual	10.60 (1.01)		

*Group effect is statistically significant at $p \leq 0.05$.

[a]Variables assessed postexplosion.

Note: Reference subgroups omitted from table.