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Examining Localized Patterns of Air Quality Perception in Texas: A Spatial and Statistical Analysis

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Environmental and human health issues associated with outdoor air pollution, such as ozone, sulfur dioxide, and other pollutants in metropolitan regions, are an area of growing concern for both policy officials and the general public. Increasing attention from the news media, new health data, and public debate over the effectiveness of clean air regulations have raised the importance of air quality in the public consciousness. While public perceptions of air quality have been studied thoroughly dating back to the 1960s, little empirical research has been conducted to explain the spatial aspects of these perceptions, particularly at the local level. Although recent studies suggest characteristics of local setting are important in shaping perceptions of air quality, the roles of proximity, neighborhood characteristics, and location have not been clarified. This study seeks to improve understanding of the major factors shaping public perceptions of air quality by examining the spatial pattern of local risk perception, the role of socioeconomic characteristics in forming these perceptions, and the relationship between perceived and scientifically measured air pollution. First, we map the spatial pattern of local air quality perceptions using Geographic Information Systems (GIS) across the Dallas and Houston metropolitan areas. Next, we explain these perceptions through local contextual factors using both bivariate correlations and multivariate regression analysis. Results indicate that perceptions of air quality in the study areas are not significantly correlated with air quality based on readings of air monitoring stations. Instead, perceptions appear to be influenced by setting (urban vs. rural), state identification, access to information, and socioeconomic characteristics such as age, race, and political identification. We discuss the implications of the findings and provide direction on how further research can provide a deeper understanding of the local contextual factors influencing public perceptions.

KEY WORDS: Air quality; environmental perceptions; Geographic Information Systems; Texas

1. INTRODUCTION

Despite improvements in overall air quality in the United States since the 1970s, air pollution continues to be an environmental problem for both health officials and the general public. A growing awareness of possible health threats associated with industrial air discharges and transportation-related exhaust has driven the issue of outdoor air quality to the forefront of public awareness. At the same time, public risk perception plays an increasingly important role in shaping environmental policy and management response systems.(1) While a large amount of work has

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examined perceptions of air quality based on national surveys and analysis of broad geographic regions, little empirical research has focused on understanding and explaining local, neighborhood public perceptions of air quality. Recent studies, primarily in Canada and the United Kingdom, suggest that localized place and setting play an important role in determining perceptions of air quality.[2–4] Spatial issues such as proximity to urban centers, local environmental characteristics, and residential setting such as urban or rural locations are poorly understood in part because past studies have examined only general notions of risk perception. In addition, identifying the relationship between perceived and monitored measures of air quality has not been possible, partly because consistent data and the technology to analyze it have not been available.[4]

This article seeks to improve the current state of knowledge about the major factors shaping public perceptions of air quality by examining the spatial pattern of local risk perception, the influence of local setting, the role of socioeconomic characteristics in forming these perceptions, and the relationship between perceived and scientifically measured air pollution. We pose the following three research questions to understand more fully how perceptions are influenced by local contextual factors: (1) What is the spatial pattern of air quality perceptions across urban areas? (2) Is there a local disconnect between perceived air quality and scientifically measured air quality? and (3) If actual local air quality measured by monitoring stations does not affect local perceptions, then what are the major contributing socioeconomic and contextual factors? To answer these questions effectively, we first map the spatial pattern of local air quality perceptions using Geographic Information Systems (GIS) across the study sites, the Dallas and Houston regions. Second, we explain these perceptions through local contextual factors using both bivariate correlations and ordinary least squares (OLS) multiple regression analysis. Results provide information to state and regional decisionmakers on what is driving public perception and guide them in crafting effective air quality plans and policies in the future.

The following section examines the past literature explaining perceptions of outdoor air pollution with a focus on the role of place, setting, and proximity to industry and urban centers. Literature on the social and cultural construction of air quality perceptions is then reviewed. Next, sample selection, variable measurement, and data analysis procedures are described. Results are then presented in two phases. First, the spatial pattern of risk perception is graphically evaluated for zip codes across the Dallas and Houston regions. Second, correlation and multiple regression analyses are conducted to better understand the major contributors to local air quality perceptions. In the final section, we discuss the implications of the results and provide guidance for future research to further enhance understanding of the local contextual factors influencing public perceptions.

2. BACKGROUND

2.1. Local Perceptions of Air Quality: Proximity, Place, and Setting

The majority of research on public opinions of air quality in the United States and United Kingdom was conducted in the 1960s and 1970s. These surveys attempted to assess the level of public awareness of air quality and understand the major factors shaping these perceptions. Over the last 40 years, major changes have taken place in the types, sources, and spatial pattern of air pollution, as well as the socioeconomic characteristics of those perceiving air quality.[3] A renewed interest in studying perceptions of air quality has emerged in the 21st century as the relationship between pollution and adverse health effects is better understood, the reporting and accuracy of air quality measurements have improved, and community members have become more active in making environmental policy.[3,4] For example, the complex network of continuous air monitoring stations that exists in most major urban areas is providing far more data at a higher level of accuracy that previously did not exist. While the environmental and social conditions may have been different four decades ago, past research lays a solid conceptual foundation for understanding the causes of air quality perceptions.

A major theme stemming from this literature emphasizes the relationship between perceived and scientifically monitored levels of air pollution. Higher levels of measured air pollution are not always associated with an increase in public awareness of environmental risk as one might expect. Several studies have found that people residing in areas of extremely high air pollution were not at all concerned or aware of these potentially dangerous levels.[5,6] For example, Dworkin and Pijawka[7] found in their study of public concern in Toronto, Canada, that the population was insensitive to the changes in air quality between 1967 and 1978. These results led the authors to be skeptical about the relationship between public perception and actual changes in air quality. More recently, when controlling for socioeconomic factors, Johnson[8] found no correlation between concern for air quality and the actual air pollution readings on the day the respondents were surveyed. Other research has shown that awareness of air pollution is significantly correlated with levels measured at monitoring stations and there is a distance decay of concern spreading outward from urban centers into rural areas.[2,9–11]

This potential disconnect between perception and scientific measurement is often conceptualized as a "halo effect" where individuals are reluctant to attribute high levels of air pollution to their neighborhood or home area.[3,12–16] Respondents in these studies consistently believe their communities or areas of place identity contain less pollution than surrounding areas. While citizens recognize the existence of serious air pollution in their general area, they tend to deny its adverse effects on themselves or that air pollution may be a problem in their specific neighborhood.[10,17] Most recently, Bickerstaff and Walker[3] confirmed the halo hypothesis in their study of residents of Birmingham, England by finding a reluctance of urban dwellers to recognize poor air quality conditions within the immediate locale. The presence of respondent denial suggests that factors other than actual pollution levels are driving perceptions of air quality. Scholars have offered alternative explanations, such as local environmental perceptions are determined by direct sensory experience (i.e., if one cannot see or smell pollutants then they must not be present), individuals refuse to accept the possibility of high environmental risk in their backyard, and perceptions are determined by media coverage and reporting of air quality conditions.

Another related theme found in the environmental perception literature is that location matters in forming perceptions of air quality more than the actual quality of the air itself. For example, Howel *et al*.[4] found strong associations between proximity to industry and perceptions of the local environment for residents living in northeast England. Interview data indicated that there was a higher level of concern for air pollution among communities located close to industrial land uses due to nuisances such as smell as well as potential risks to human health. These findings are consistent with previous research demonstrating that proximity to industrial uses increases public concern.[2,18]

The notion that proximity contributes to forming environmental views can also be translated into the general setting in which an individual resides. For example, Tremblay and Dunlap[19] found that rural residents were less concerned with environmental problems than those living in urban settings. Lowe and Pinhey[20] confirmed these rural anti-environmental conclusions in a national study focusing on a respondent's place of socialization. These findings are consistent with other research indicating that those whose livelihood is based on extractive activities are less likely to be concerned with environmental conservation.[21] More recent empirical research disputes the rural anti-environment hypothesis and instead suggests increasing environmental concern in nonmetropolitan areas.[22,23] Research specific to air quality has shown that residents of rural areas perceive lower levels of pollution and are less concerned with serious environmental problems than their urban counterparts.[24,25] One theory behind this phenomenon states that residents will essentially "vote with their feet" by choosing to live in places they believe are free of air pollution. Rural settings, in this case, appear more attractive than urban neighborhoods.

2.2. The Social and Cultural Construction of Local Air Quality Perceptions

A third theme stemming from the literature is that perceptions of air quality are not simply a function of place, but are socially and culturally constructed through a rich tapestry of experience, behavior, and socioeconomic status.[26] Several studies have linked characteristics such as age, income, and race to views of and exposure to air quality. For example, when comparing different age groups, Howel *et al*.[4] found that older residents were significantly more likely to rate the local air quality as low. This result can be explained by the possibility that older residents have memories of bad air pollution in the past and have experienced an improvement of overall conditions over time.[27] The findings for income related to perception are less consistent. Dworkin and Pijawka[24] argue that individuals of high socioeconomic status may be more concerned and more knowledgeable about environmental problems such as air pollution. Tiefenbacher and Hagelman[25] support this notion by finding that high income groups are more likely to live nearer airborne toxic emitting facilities in Texas and therefore more concerned with its associated risks. In contrast, Bickerstaff and Walker[3] found that low socioeconomic status groups identified local air quality as worse than the rest of the city.

Race and equity issues have received a great deal of attention in the literature focusing on the hypothesis that nonwhite minorities are located closer to air pollution sources and therefore are more vulnerable to associated health risks. However, comparatively few studies have been conducted to determine how different racial groups perceive the quality of the surrounding air. Johnson[8] was one of the few researchers to focus on the relationship between race and beliefs about outdoor air quality. He found that nonwhites in Philadelphia are more likely to rate air quality as poor and are potentially more attentive to air quality information than whites. Due to the paucity of research in this area, it has been suggested that additional study is needed to determine how aware various socioeconomic groups are of the hazardous environment in which they live, particularly in Texas.[28]

Information, awareness, and exposure to risk communication messages are considered important predictors of risk perception.[1] Specifically, the news media can amplify the social construction of risk to human health.[29] In metropolitan areas with more than 350,000 people, state and local agencies are required to report the Air Quality Index (AQI) to the public daily. When the AQI is above 100, they must also report which groups (e.g., children, people with asthma, or heart disease) may be sensitive to the specific pollutant. If two or more pollutants have AQI values above 100 on a given day, agencies will report all the groups that are sensitive to those pollutants. Although it is not required, many smaller communities also report the AQI as a public health service. The AQI and "Ozone Action Day" notifications are reported daily in local newspapers, on television, and over the radio. The AQI is an index for measuring and reporting daily air quality. The index is computed based on the pollutant with the highest reading in an area. The AQI is an index of five major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. This index is a risk communication tool aimed at providing information to area residents about air quality in a timely manner and understandable format.[2] Therefore, access to the AQI and related information may be a critical factor in forming local perceptions of air quality regardless of place, proximity, and setting of residence.

Another way to understand how individuals construct their perceptions of air quality is through the formation of mental models. Mental models are internally created representations of reality that individuals use to explain and predict specific phenomena.[30] They act as cognitive frames through which the world is understood and can help explain individual perceptions. These constructs are particularly important in shaping an individual's understanding of complex problems and systems. Mental models have been used as a qualitative methodological approach to help explain gaps between expert and public knowledge of technological and environmental problems, such as global climate change.[31,32] Morgan *et al*.[33] use mental models to improve risk communication between experts and laypersons. By identifying knowledge gaps between these two groups, the authors are able to find opportunities to enhance communication and facilitate consensus over topics of risk. Mental models are typically unstable, without well-defined limits, unscientific, and largely incomplete.[34,35] These characteristics tend to produce a wide variation in perceptions associated with environmental risk such as air quality. Mental models not only tend to be vastly different for the same problem, but very few accurately portray the complexity and extent of the issue. Although this area of study has yet to be applied specifically to air pollution, there is no doubt that the formation of mental models and the environment in which they are constructed may play an important role in the construction of air quality perceptions.

3. RESEARCH METHODS AND DATA ANALYSIS

3.1. Research Sites

Two of the largest metropolitan areas in Texas—the Dallas-Fort Worth and Houston-Galveston areas (hereafter referred to as Dallas and Houston)—were selected as study sites. Air pollution levels in both areas consistently exceed National Ambient Air Quality Standards and have been designated as "nonattainment areas" by the Environmental Protection Agency (EPA). The major source of emissions in these areas is on-road vehicles. For example, carbon monoxide emissions exceeded 1,175 tons per year in the Houston area and 826 tons per year in the Dallas area. Industrial point sources and nonroad mobile sources are also large contributors.[36] The Dallas-Fort Worth study region contains 23 active continuous air monitoring stations (CAMS) within the following 10 counties: Denton, Collins, Parker, Tarrant, Dallas, Rockwall, Hood, Johnson, Ellis, and Kaufman. A total of 28 active CAMS are maintained in the Houston study area, which consists of Montgomery, Harris, Galveston, and Brazoria Counties.

3.2. Sample Selection

Residents in both regions were surveyed as part of a statewide telephone survey using a random-digit dialing (RDD) sampling frame based on households with working telephones. In each household, the adult resident with the most recent birthday was selected for an interview. The Institute for Public Policy (IPP) at the University of New Mexico conducted the survey using computer-assisted telephone interviewing (CATI). Overall, 870 survey interviews were completed between August 10 and September 9, 2001. The response rate was 43% and the cooperation rate was 55%. From the statewide survey, 378 residents were sampled and selected for analysis in Dallas and Houston.

3.3. Concept Measurement

The dependent variable for the study is the degree to which residents believe the air in their local area is polluted. This perception variable was measured through the survey by asking the following question: "Using a scale from one to seven where one is very bad and seven is very good, how would you rate the air quality in your local area?" Independent variables are socioeconomic characteristics (i.e., political party identification, age, income, education, race, etc.), perceptions of local air pollution sources (based on six different sources), sources of information on air quality, and perceptions of air quality for Texas as a whole as well as for other cities in the United States outside of Texas (see Appendix).

Scientifically measured levels of air quality were calculated based on readings from continuous air monitoring stations (CAMS) located within the study areas. Levels of the following five air pollutants were recorded daily over a one-year period leading up to the time of the survey in August 2001: carbon monoxide (CO), nitrogen dioxide (NO), ozone (O_3), particulate matter less than 2.5 μm ($PM_{2.5}$), and sulfur dioxide (SO_2). An average pollution level was calculated for each individual pollutant as well as for the combination of all of the pollutants. Each individual respondent was assigned an average air quality reading based on their proximity to the nearest monitoring station.

Neighborhood setting variables were measured using GIS analytical techniques. Using the U.S. Census boundary files, respondents were coded as either within or outside of an Urbanized Cluster (UC) or Urbanized Area (UA). By definition, a UC or UA consists of census blocks or block groups that have a population density of at least 1,000 persons per square mile and neighboring census blocks with a population density of at least 500 persons per square mile. All areas that are not within a UA or UC are designated as rural.

GIS analytical techniques were also used to map and analyze the spatial distribution of air perception in each region. For only this phase of analysis (all other analyses were conducted at the individual level), we used zip codes, a logical area unit representing a collection of streets or local grouping of households, to graphically illustrate the patterns of local perceptions over a large land surface. Survey respondents were spatially joined to their corresponding zip codes as reported in the survey and individual perceptions of local air quality were then averaged by zip code.

3.4. Data Analysis

The data were analyzed in three phases. First, we took a broad spatial view of air quality perceptions by mapping and describing responses according to zip code in Houston and Dallas. Grouping responses for perceived air quality by zip code ("zones") allowed us to better visualize the general spatial pattern of perceptions across the two study regions. Alternatively, mapping perceptions as individual points would be extremely difficult to interpret at such a broad scale. Second, we took a finer grained approach to analyses by examining influences on air quality perceptions at the individual level. Correlation analysis was conducted between local perceptions of air quality and independent variables grouped into the following categories: air monitoring readings, quality, state and national air quality perceptions, socioeconomic characteristics, perceived sources of local air pollution, sources for air quality information, and local setting. Zero order correlations allowed us to make an initial assessment of factors that influence air quality perceptions by examining a large number of variables. Finally, a subset of variables was selected and analyzed using ordinary least squares (OLS) multiple regression to explain their effects on local air quality perceptions in each study area. This analytical approach allowed us to further identify the factors driving air quality perceptions in a more refined model that statistically controls for all other variables. Several statistical tests for reliability were conducted to ensure the OLS estimators were best linear unbiased estimates (BLUE). Tests for model specification, multicollinearity, heteroskedasticity, and spatial autocorrelation revealed no violation of regression assumptions.

4. RESULTS

4.1. Spatial Pattern of Air Quality Perception

Figs. 1 and 2 illustrate the mosaic of air quality perceptions by zip code across Dallas and Houston.

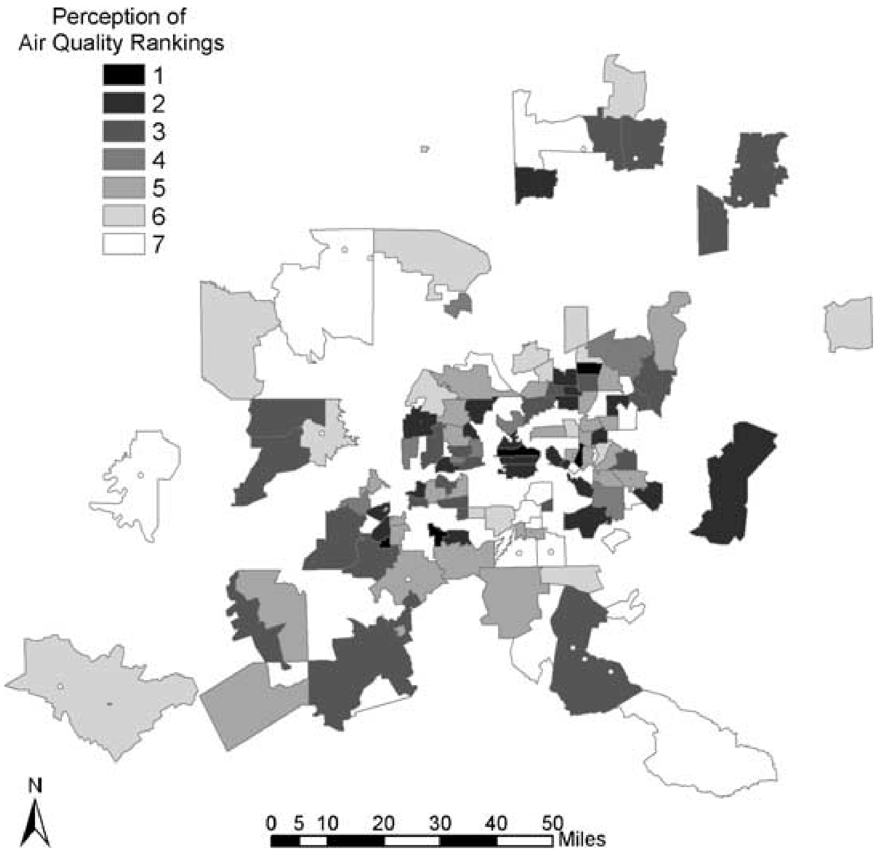

Fig. 1. Perceptions of air quality by zip code in Dallas.

Darker shades represent zip codes in which respondents believe their local air quality is comparatively poor. Both metropolitan areas exhibit a general pattern of poor air quality perceptions concentrated at the urban core with perceptions becoming cleaner as zip codes extend outward into suburban and rural areas. This spatial pattern is particularly pronounced in Dallas where there is a well-defined ring of very good air quality ratings at the outer-most extent of sampled zip codes and a second ring of medium ratings closer toward the city center. Respondents who believe their local air quality is very polluted are, for the most part, located within zip codes at the urban center of the study area. It should also be noted that the urban centers of both cities have the most heterogeneous pattern of air quality perceptions, representing a spatial mix of views on environmental quality.

Tests for spatial autocorrelation to determine if there is a spatial clustering of high or low air quality ratings in the Dallas study area are not statistically significant. However, an independent two-sample test of means between air perception zones in urban areas and those in rural areas is highly significant where $p < 0.05$ (Table I). Respondents living in zip codes in rural settings perceive the air to be significantly cleaner than those living in urban zip codes. While we observe a general pattern of air quality ratings based on proximity and spatial configuration, there are anomalies that deserve mention. In Dallas, the northern and eastern portions of the study area contain zip codes representing an average belief that the local air quality is very poor. This area is located adjacent to a zone showing that perceptions of air quality are very good (Fig. 1). Further investigation of the socioeconomic characteristics of respondents in the anomalous zip code reveals residents are generally rural dwelling individuals with lower levels of education, less wealthy, and conservative in their political affiliation. This result provided initial evidence that local air quality perceptions are driven by some factor other than what is actually measured by scientific instrumentation.

As mentioned above, Houston has a similar spatial pattern of local air quality perceptions where those who respond with poor ratings are located within zip codes in the urban core while respondents

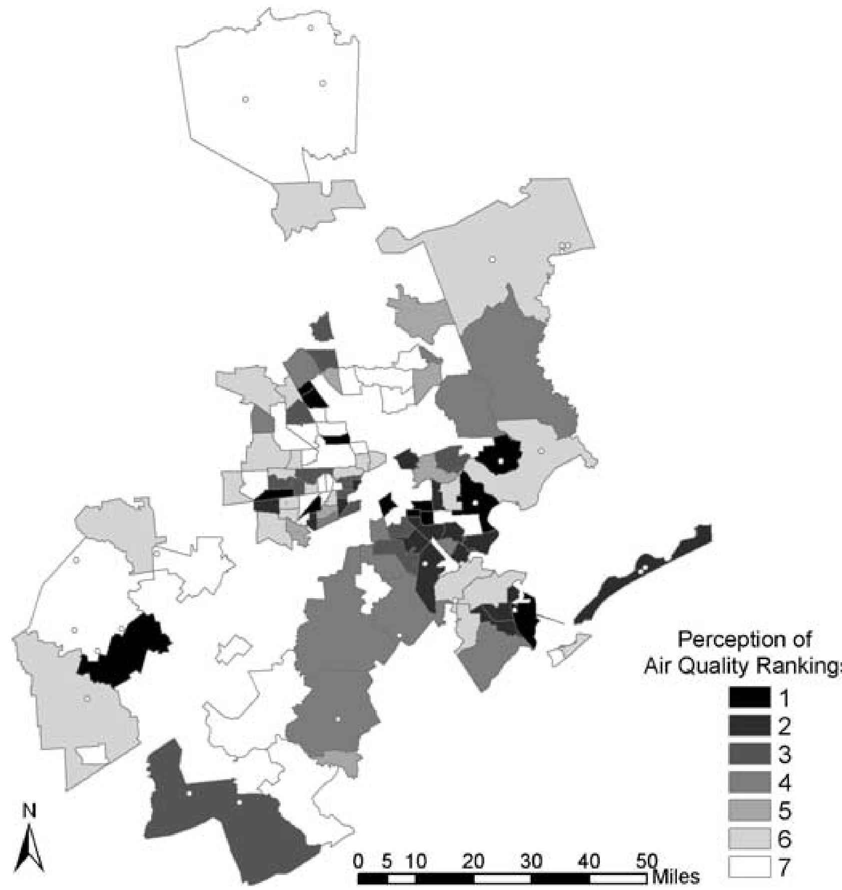

Fig. 2. Perceptions of air quality by zip code in Houston.

in outlying metropolitan zones have the highest ratings (Fig. 2). Compared to Dallas, however, the rings of perception for Houston are not as distinct and there is a greater degree of heterogeneity with respect to perceptions outside of the city center. Tests for both spatial autocorrelation and a two-sample test of means between perceptions in urban and rural zones are not statistically significant (Table I). This result most likely picks up on the sprawling development pattern of the Houston region where there is a weak distinction between urban and rural land uses. As for Dallas, we investigated anomalous perception zones representing very poor air quality ratings to the southwest and east of the Houston study area located adjacent to several zones in which respondents rate the local air as very clean. Socioeconomic characteristics for this zone are consistent with findings for Dallas in that respondents are generally rural dwelling, uneducated, lower income males with conservative political identification. These results again support the hypothesis that air quality perceptions may not be significantly related to actual air quality based on monitoring stations.

Table I. Tests of Means Comparing Perceptions in Urban and Rural Areas

Land Use	Mean Rural Perceptions	Mean Urban Perceptions	*t*-Test	*p*-Value
Dallas	4.82 ($n = 81$)	4.21 ($n = 46$)	1.99	0.04
Houston	3.82 ($n = 73$)	3.97 ($n = 31$)	−0.40	0.68

4.2. Correlation Analysis for Local Air Quality Perceptions

Bivariate correlation analysis acted as a first step in understanding the major factors driving local perceptions of air quality in Dallas and Houston. If, in fact, views on the degree of pollution in a local area are not based on scientifically measured air quality readings, it is important to determine which factor or set of factors has contributed to the formation of community perceptions.

The air monitoring station networks in Dallas and Houston provide the best available data to examine the relationship between air quality perceptions and technical measurement of air conditions. Perceptions were correlated with an average reading from air quality monitoring stations over a one-year period leading up to the time of the survey. Using a measure based on the combination of five different pollutants (used to determine daily air quality indexes by the U.S. EPA), results indicate a disconnect between local perceptions of air quality and actual measurement. For both Dallas and Houston, there is a very weak positive correlation between the average air pollution recorded in a locale and the perceptions of air quality within that locale (Table II). While the relationship is not statistically significant, the direction of the correlation indicates that as the level of air pollution increases, respondents perceive their local air to be cleaner.

Place-based perception variables address the "halo" hypothesis presented above that residents are unwilling to accept air pollution or environmental risk in their particular locality. For example, in Dallas ($p < 0.01$) and Houston ($p < 0.000$) respondents believe that as air pollution problems in Texas become more serious, local air quality is significantly worse. For areas outside of the state, however, respondents have a different view of air quality. In both study areas, residents strongly believe that, at the 0.001 level of significance, the air quality in Texas cities is much better than air quality in other major cities in the United States.

Table II. Correlation Analysis for Local Air Quality Perceptions

Variable	Dallas	Houston
Air Monitoring Station Readings		
Air quality average	0.00	0.09
Air quality maximum	−0.11	0.02
Place-Based Perception Variables		
How serious of a problem is AQ in Texas?	−0.23****	−0.43****
How does AQ in major Texas cities compare to other major U.S. cities?	0.26****	0.49****
Local Setting Variable		
Urban/rural	−0.15**	−0.06
Perceived Source of Local Air Pollution		
Oil refineries	−0.13**	−0.20***
Manufacturing	0.07	−0.10
Auto exhaust	−0.14**	−0.20**
Dust from construction	0.22***	0.10
Dust from agriculture	0.04	0.06
Socioeconomic Variables		
Political identification	0.19***	0.05
Education	−0.04	0.01
Age	0.12*	0.19**
Gender	−0.08	−0.03
Income	−0.01	0.04
Race	0.11	0.03
Source of State and Local News		
Television	0.16**	0.01
Newspapers	−0.00	0.04
Radio	−0.11	0.04
Friends and groups	−0.12*	−0.13*
Other	−0.08	−0.06
Media that report air quality conditions	0.15**	0.09

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$; ****$p < 0.001$.

Urban and rural clusters as defined by the U.S. Census represent the setting in which respondents live and their general proximity to industrial, residential, agricultural, and other human activities. Respondents located in predominantly urban settings in Dallas perceive the local air to be significantly more polluted ($p < 0.05$). In Houston, however, this relationship is not statistically significant. This urban-rural dichotomy for air quality perceptions is consistent with the results of the first phase of analysis where we found a significant difference between views of respondents living in rural areas outside of the City of Dallas and those residing in the urban core.

Perceptions of the greatest source of air pollution in Texas are also correlated with perceptions of local air quality. Perceived pollution stemming from oil refineries and automobile exhaust (the dominant sources of pollution in the state) is correlated with a significant decrease in perceived local air quality for both study areas ($p < 0.05$). When respondents in Dallas perceive the greatest source of pollution to come from construction dust, they perceive local air quality to be significantly cleaner. This result may stem from the belief that while construction dust is highly visible, it has less adverse effects on the environment than pollution emitted from automobiles and oil refineries.

Socioeconomic variables have been shown to be correlated with views of local air quality and should be considered important factors in this study when explaining the variation in perceptions (Table II). In Dallas, political identification (PID) is significantly correlated with local air quality perceptions where more conservative respondents believe the air is cleaner. Age is statistically significant for Dallas ($p < 0.1$) and Houston ($p < 0.05$). In this instance older respondents tend to perceive their local air as more polluted.

Finally, we tested the assumption that reports by the news media and sources from which the public accesses environmental information help shape perceptions of air quality in metropolitan regions.(2) Generally, the type of news source seems to be important in influencing air quality ratings. Respondents in

Dallas who receive their news primarily from television perceive their local air quality to be significantly cleaner. Respondents in both Dallas and Houston who receive news mostly from friends, on the other hand, perceive their local air to be significantly more polluted ($p < 0.1$). Grouping news sources into those that regularly report air quality indexes and those that do not is more revealing. We find that respondents who obtain news from sources that consistently report on air quality in the Dallas area are significantly more likely ($p < 0.01$) to believe their local air quality is good, but this is not the case in the Houston area.

4.3. Regression Analysis Explaining Local Air Quality Perceptions

Bivariate correlation analysis confirms many of the findings of past studies and increases understanding of the factors contributing most to perceptions of local air quality, particularly in Texas. However, the impact of these factors cannot be fully understood without controlling for other factors when explaining the variation in air quality perceptions. OLS multivariate regression analysis allowed us to examine the parceled effects of a focused set of independent variables on air quality perceptions. Because of the relatively small sample size, we selected a subset of variables with which to explain the variation in perceptions for Dallas and Houston (Tables III and IV). For scientifically measured air quality ("actual air quality") we chose the combined average of five pollutants since no one pollutant seemed to consistently drive air quality perceptions. Both place-based perception variables were selected for inclusion in the model because of their strong correlations with local air quality perceptions. Rural and urban clusters were analyzed in the model as a dichotomous variable. For the perceived greatest sources of air pollution set of variables, we chose the dominant sources in each city: exhaust, oil refineries, and dust from construction. Socioeconomic control variables included income, education, age, political identification (PID), and race (white/nonwhite). Finally, for major source of news, we included a dichotomous variable representing those sources that regularly report air quality indexes (1) and those that do not (0).

Regression results for Dallas confirm that actual air quality readings based on monitoring stations are not related to perceptions of local air quality (Table III). While scientifically measured local air quality does not appear to significantly influence local perceptions, views of air quality in other areas do make a difference. Respondents in Dallas believe the air quality in their local area is very good compared to other U.S. cities outside of Texas. Also, when controlling for other factors, the urban-rural dichotomy described above remains significant at the 0.01 level where respondents living in urban areas believe the air they breathe is more polluted. Perceived source of pollution also remains a statistically important factor in multiple regression analysis. Pollution from oil refineries is significantly correlated with perceptions of poor local air quality even though there

Table III. Explaining Air Quality Perceptions in Dallas

Variable	Coefficient	Standard Error	t-Value	Significance
Avg. air quality readings	−0.22	0.27	−0.82	0.416
Air quality in TX	−0.07	0.06	−1.24	0.216
Air quality in TX compared to other cities	0.35	0.11	3.14	0.002
Source exhaust (automobile)	−0.21	0.32	−0.65	0.515
Source oil refineries	−2.77	0.80	−3.44	0.001
Source construction dust	0.62	0.51	1.21	0.227
Political identification	0.04	0.08	0.53	0.598
Income	−0.01	0.04	−0.39	0.694
Education	0.11	0.10	1.10	0.272
Age	0.01	0.00	1.74	0.084
Race	0.70	0.30	2.32	0.021
Air quality media reports	0.45	0.35	1.26	0.211
Urban/rural	−0.88	0.27	−3.26	0.001
Constant	4.39	0.83	5.23	0.000
N	170			
F-ratio (13, 156)	4.73			
Significance	0.00			
Adjusted R^2	0.222			

Table IV. Explaining Air Quality Perceptions in Houston

Variable	Coefficient	Standard Error	t-Value	Significance
Avg. air quality readings	0.18	0.34	0.54	0.587
Air quality in TX	−0.21	0.06	−3.58	0.000
Air quality in TX compared to other cities	0.65	0.13	4.97	0.000
Source exhaust	0.46	0.36	1.29	0.200
Source oil refineries	−0.11	0.40	−0.027	0.787
Source construction dust	0.40	0.69	0.58	0.560
Political identification	−0.09	0.09	−1.00	0.318
Income	−0.09	0.05	0.37	0.709
Education	−0.02	0.09	−0.23	0.815
Age	0.01	0.00	1.43	0.154
Race	0.32	0.30	1.06	0.289
Air quality media reports	−0.00	0.38	−0.02	0.984
Urban/rural	−0.12	0.27	−0.45	0.656
Constant	5.42	0.98	5.52	0.000
N	156			
F-ratio (13, 142)	5.12			
Significance	0.000			
Adjusted R^2	0.313			

are far fewer oil refineries in the Dallas metropolitan area than in Houston. Socioeconomic variables also continue to be significant factors in explaining local air quality perceptions. On average, older members of the population think the air they breathe is significantly less polluted. Interestingly, when controlling for socioeconomic and other variables, nonwhite populations in Dallas are significantly more likely to rate air quality as better compared to white populations, which corresponds with previous research on the topic.[8]

Based on the regression results for respondents in Houston, we again find no statistically significant relationship between actual air quality measurements and perceptions of local air quality (Table IV). A strong state-level "halo" effect persists in this study area, where respondents' views of local air quality are influenced by their belief that pollution in other non-Texan cities across the Unitied States is far worse. Respondents, however, do not seem to separate the quality of the local air from the air quality in Texas. Poor air quality perceptions of Texas strongly influences views that local air quality is also very poor. Consistent with the correlation analysis above, neighborhood setting (urban-rural cluster) does not drive local air perceptions, as is the case in Dallas where there exists an urban-rural dichotomy in environmental perceptions.

5. DISCUSSION

Based on the three phases of analysis, we find that perceptions of local air quality are driven not by actual readings from air monitoring stations, but by other factors such as sense of place, proximity, and neighborhood setting. This may be no surprise since many air pollutants cannot be seen or felt by a casual observer and mental constructs of air quality do not necessarily depend on scientific understanding. Yet, this disconnect between perceptions and scientifically measured air quality is an important finding because it requires us to examine rival hypotheses to explain the variation in beliefs about air pollution. Specifically, the previously documented "halo" effect where residents are reluctant to attribute high levels of air pollution to their neighborhood or home area provides insight into the role of place-based perceptions in shaping views on air quality in Texas. Unlike other studies that demonstrate a halo around a specific neighborhood,[3] our research shows a perception-based halo around the entire state. This extended halo of clean air perceptions may be largely attributed to a cultural phenomenon specific to Texas. In many instances, Texans tend to identify more strongly with their state rather than with a specific city or neighborhood. While it is beyond the scope of this study to examine sense of place identifiers, we argue that a strong affinity with Texas reduces the distinction between local and state perceptions, but intensifies the distinction between state and other areas when it comes to rating air quality. Regardless of its basis, this halo of optimism encircling the state seems to exist in spite of the reality that Houston and Dallas have some of the dirtiest air in the country.

The perceived source of pollution also appears to impact perceptions of air quality in Dallas and Houston. In correlation analysis, respondents in both study areas associate pollution from oil refineries and car exhaust with poor local air quality. It is unclear whether these perceptions are driven by media reports or are influenced by individual sensory experiences, but the type of pollution seems to make a perceptual difference regardless of whether it is associated with actual air quality readings. Nevertheless, in the multiple regression phase of analysis, only pollution from oil refineries remains a statistically significant predictor.

It is important to note that air quality perceptions in Dallas have marked differences from those in Houston and that perceptions in general may be contingent on an area's overall setting, development patterns, industry base, and urban culture. For example, an important result from this study is that respondents living in zip codes in concentrated urban centers are more likely to perceive the air as more polluted than those living in suburban and rural outlying areas. In correlation and regression analysis, this urban-rural dichotomy in views is significant for Dallas, but not for Houston. We argue that perceptions of air quality according to neighborhood setting may not differ in the two cities, but rather it is the land-use patterns causing the conflicting results. Houston has a sprawling pattern of land development (due in part to the fact that there are no zoning regulations for the City of Houston) where there is less distinction between urban, suburban, and rural areas. The heterogeneous pattern of land use in Houston blurs the statistical distinction between urban and rural perceptions. In fact, while the statistic for the test of means in the first phase of analysis is nonsignificant for Houston, the direction is negative, indicating respondents in urban areas perceive the air to be cleaner than those in rural areas. In contrast, Dallas has a more defined urban core and separation between urban and rural land uses.

Another example of the differences in perceptions among the two study areas is the source of news providing information about air quality. Media sources that consistently report air quality conditions have a much stronger effect on shaping the perceptions of respondents in Dallas than those residing in Houston. This result supports the need for contingent-based policies geared to the specific characteristics of the Dallas study area. Assuming that news sources influence perceptions, then the manner in which the media reports on environmental conditions is a critical aspect in predicting how the public in Dallas will view air quality and respond to government policies that seek to improve local and regional conditions. In this respect, more accessible and far-reaching communication channels should be established to provide the broader public with the best available information on air quality conditions. Information dissemination may help to reduce the urban-rural dichotomy we observed in terms of perceptions and possibly reduce misconceptions over the actual quality of local outdoor air.

The interpretation of the results indicate that they are scale dependent, where attributes of the local neighborhood may drive air quality perceptions more than the quality of the air itself. Individuals are nested within a neighborhood, a rural or urban region, a metropolitan area, and the State of Texas. Behavioral and social data commonly have a nested structure based on organization, administrative, or geographic scales. While OLS regression analysis provides initial insight into the factors impacting perceptions of air quality, hierarchical linear modeling may reveal an even clearer picture by addressing the scale-dependent nature of the data. Within the hierarchical linear model, each level in the data structure (e.g., repeated observations within persons, persons within neighborhoods, neighborhoods within states) is formally represented by its own submodel. Each submodel represents the structural relations occurring at that level and the residual variability at that level. In this way, the influence of multiple scales can be examined as an integrated part of the model.

6. CONCLUSION

The results of this study indicate that public perceptions of air quality in Texas are driven not by actual air quality conditions as measured by air monitoring stations. Spatial and correlation analyses instead demonstrate that other factors such as sense of place, neighborhood setting, source of pollution, and socioeconomic characteristics appear to shape perceptions. Policymakers thus cannot rely on scientific data alone to drive a public decision-making process, but also must consider location-based factors, the specific make-up of the population, and the venues through which this population receives information on environmental conditions.

Specifically, public programs must break down the persistent halo of optimistic views regarding air quality through education and strategies targeted at segments of the population that may be most accepting of cleaner air initiatives. If the news media is critical to shaping the public's perceptions of air quality, then government organizations must ensure that television, radio, and printed news sources receive accurate information, convey this information in an easily understandable format, and reach a broad audience. Education campaigns should also be implemented outside of media channels to make residents in local neighborhoods aware of how their individual behaviors can adversely impact air quality. Education-based strategies should be aimed first at parts of the population that believe the air is polluted (i.e., older residents, living in urban areas, in close proximity to oil refineries or heavy automobile traffic), whether it is consistent with air quality readings or not. These residents should be more receptive to clean air policies and behavioral changes that would improve air quality. Once a constituency of support is achieved in areas with the greatest environmental concern, policies and programs can be directed to segments of the population that may be more difficult to convince. The public initiative would, of course, be more precise and persuasive if there was a more extensive network of air monitoring stations throughout metropolitan regions in Texas.

In general, using GIS to map and spatially analyze the mosaic of air quality perceptions across Dallas and Houston helps form a clearer picture of how local context influences beliefs on environmental conditions. This approach also provides insight into explaining the variation of perceptions across relatively large geographic areas. However, our study was bounded by data limitations and should be considered an initial examination of the factors contributing to local perceptions of air quality. Additional data and further research are needed to form a more complete understanding of the topic. First, future studies should further unpack the role of neighborhood setting in shaping perceptions. Variables such as surrounding land use, noise, and odors need to be investigated in more detail. Second, larger samples covering a broader geographic area would increase statistical power and improve the interpretation of the results, particularly in the case of multiple regression analysis. The sample size for this study limited the number of independent variables that could be included in the models. Third, a larger number of metropolitan areas located in different parts of the country (i.e., multiple states) would allow for a more in-depth comparative analysis and add additional insight into the factors driving environmental perceptions. Fourth, more consistent and accurate scientific data are needed to measure air quality conditions. Monitoring stations occasionally go offline or fail to record a specific pollutant, which can result in missing data, making it difficult to assess air conditions over a short time frame. Additional monitoring stations would also allow for more accurate predictions for air quality and enable researchers to analyze conditions over a more extensive geographic area. Also, more precise measurements would allow researchers to more closely link the recorded air quality with the time of the survey call. In this instance, analyses could detect temporal variations in air quality because respondents would be reacting to conditions they just experienced. Fifth, overlaying spatial patterns of air quality perceptions with sources of heavy air pollution, such as oil refineries, gas stations, and heavily trafficked roads, may provide additional insights into the factors influencing of public perception. Air quality perceptions may be shaped more by surrounding activities and proximity to heavy industry than by scientifically measured pollution levels.

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APPENDIX: SURVEY QUESTIONS

Dependent Variable—Perception of Local Air Quality

Using a scale from one to seven where one is very bad and seven is very good, how would you rate the air quality in your local area?

1 Very Bad—7 Very Good

Independent Variables

Air Quality in Texas

Using a scale from zero to ten, where zero is not at all serious and ten is extremely serious, how serious a problem is air pollution in Texas?

0 Not At All Serious—10 Extremely Serious

Texas Cities Compared to Other U.S. Cities

To the best of your knowledge, how does air quality in major Texas cities compare to air quality in major cities in other states?

Much better than in other major cities or states
A little better
About the same
A little worse
A lot worse

Sources of Pollution in Texas

To the best of your knowledge, which of the following is the greatest source of air pollution in Texas?

Air emissions from oil refineries
Air emissions from manufacturing plants
Exhaust from cars, trucks and buses
Dust from construction
Dust and other emissions from farming and ranching

Political Ideology

On a scale of political ideology, individuals can be arranged from strongly liberal to strongly conservative. Which of the following categories best describes your views?

1 Strongly Liberal—7 Strongly Conservative

Age

How old are you?

Gender

As part of the survey, I am required to ask: are you male or female?

Income

I'm going to read you some broad income categories. Please STOP me when I get to the one that includes the estimated annual income for your household.

Less than $10,000
10 to $20,000
20 to $30,000
30 to $40,000
40 to $50,000
50 to $60,000
60 to $70,000
70 to $80,000
80 to $90,000
90 to $100,000
More than $100,000

Race

From the following options, do you consider yourself to be:

American Indian
Asian
Black
Hispanic
White non-Hispanic
Something else

News and Information Source

What source of information do you most rely on for your local and state news?

Television
Newspapers
Radio
Magazines
Friends and groups
Other

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