Proximity (Mis)perception: Public Awareness of Nuclear, Refinery, and Fracking Sites

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Whether on grounds of perceived safety, aesthetics, or overall quality of life, residents may wish to be aware of nearby energy sites such as nuclear reactors, refineries, and fracking wells. Yet people are not always accurate in their impressions of proximity. Indeed, our data show that only 54% of Americans living within 25 miles of a nuclear site say they do, and even fewer fracking-proximal (30%) and refinery-proximal (24%) residents respond accurately. In this article, we analyze factors that could either help people form more accurate perceptions or distort their impressions of proximity. We evaluate these hypotheses using a large national survey sample and corresponding geographic information system (GIS) data. Results show that among those living in close proximity to energy sites, those who perceive greater risk are less likely to report living nearby. Conversely, social contact with employees of these industries increases perceived proximity regardless of actual distance. These relationships are consistent across each site type we examine. Other potential factors—such as local news use—may play a role in proximity perception on a case-by-case basis. Our findings are an important step toward a more generalizable understanding of how the public forms perceptions of proximity to risk sites, showing multiple potential mechanisms of bias.

KEY WORDS: Energy sites; GIS; proximity; risk perception

1. INTRODUCTION

Living near sites such as nuclear reactors, refineries, and fracking wells can cause anxiety. Sites like these can pose high-magnitude risks to human health, although the likelihood is low (e.g., Bertazzi, Pesatori, Zocchetti, & Latocca, 1989; Mitka, 2012; Vesely & Rasmuson, 1984). The proximity of such sites to one's residence can factor into important life decisions like home ownership or beginning a family

(Boyle & Kiel, 2001; Doyle et al., 2000). The not-in-my-backyard (NIMBYism) phenomenon, in which locals oppose new development, is a manifestation of such concerns (Lima, 2004; Lima & Marques, 2005). In addition, living near these sites may be undesirable to some solely on aesthetic grounds (Kiel & McClain, 1995). There also are desirable consequences from knowing that one lives near a particular site. For instance, this knowledge can lead residents to develop plans of action in case of complications or emergencies (Cuite, Schwom, & Hallman, 2016; Perko, Železnik, Turcanu, & Thijssen, 2012; Zeigler, Brunn, & Johnson, 1981).

However, people are not always correct in their impressions of whether they live near energy sites. Indeed, our data show that only 54% of Americans living within 25 miles of a nuclear site say they do, and even fewer fracking-proximal (30%) and refinery-proximal (24%) residents respond

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accurately. There is ample evidence that factors beyond reality affect beliefs about one's surroundings, and of proximity, in particular (Cesario & Navarrete, 2014; Craun, 2010; Giordano, Anderson, & He, 2010; Howe, 1988). In this article, we analyze what factors correlate with perceived proximity to three distinct types of sites: nuclear sites, refineries, and fracking wells. We model how orientations toward information (risk perception, general science knowledge) and access to sources of information (news consumption, social contact) relate with perceptions of proximity.

As outlined shortly, each of these factors can lead to correct beliefs about one's proximity to energy sites. At the same time, they also can have a distorting effect, making people believe that they live closer (or farther) than they do in actuality. Watching local news, for instance, could yield a better understanding of where these sites exist, or could correlate with the belief that these sites are more proximate than they are in reality. We evaluate perceived proximity using a large national survey sample and corresponding GIS data that allow us to know exactly how proximate each respondent is from one of these sites.

Examining perceived proximity across three different types of sites allows us to move research on proximity perception forward. We find that risk perception and social contact are consistently associated with proximity misperception. However, our results show that it is not the case that these factors solely promote correct or incorrect beliefs. Rather, context—in this case, actual distance—is key. Dependent on actual distance, factors like risk perception and social contact can increase the probability that one's reported proximity is accurate for some, but increase the probability that one inaccurately reports that one lives nearby for others. Ultimately, our findings illuminate barriers to successful information campaigns, and potential ways to overcome them.

2. LITERATURE REVIEW

Many factors influence people's perceived proximity to energy sites. Most obviously, how far people actually live from these sites should affect whether or not they report living nearby. Our main interest, however, is in understanding what else matters after taking into account the reality of whether a site is actually nearby. In the sections that follow, we review two distinct theoretical lines of argument about how such sources may affect proximity impressions: one concluding that the sources should increase the

probability of correct beliefs and a second suggesting that they may result in misperceptions of one's proximity.

2.1. Correct Perceived Proximity

The first line of theory posits that perceived proximity will be more accurate for some people compared to others. When people know more about science, believe that sites are risky, use news media, or know others working in related fields, they may be more aware of whether they live near energy sites. We review the theory supporting each idea in turn.

2.1.1. Science Knowledge

Preexisting domain knowledge should exert a strong influence on individuals' awareness of their proximity to energy sites. Research consistently shows that those equipped with a store of background knowledge are more knowledgeable about current events (e.g., Zaller, 1992). In the context of science, those with more background scientific knowledge should be better versed in the science and technological sites in their vicinity. Individuals who possess a large amount of domain knowledge have more sophisticated schemata to organize it, and this aids in their uptake of new information (Converse, 1975; Markus & Zajonc, 1985). Similar patterns have been shown in the science (e.g., climate change, Nisbet, Cooper, & Ellithorpe, 2015) and risk (e.g., nuclear power, Perko et al., 2012; Perko, Thijssen, Turcanu, & Van Gorp, 2014; Perko, van Gorp, Turcanu, Thijssen, & Carle, 2013) domains: prior domain knowledge helps to explain public awareness of specific issues. Following this literature, we propose that general science knowledge will predict a greater probability of correct proximity perceptions.

2.1.2. Risk Perception

Individuals who perceive these technologies as high risk should be more likely to know whether these sites are nearby. We propose this relationship because negative information and perceptions of risk should lead people to seek, and retain, more information about these potential harms. Negative information shapes judgment more profoundly than positive information (e.g., Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) and people are drawn toward negative information about political matters

(e.g., Meffert, Chung, Joiner, Waks, & Garst, 2006; Soroka, 2014). Individuals believing that these features have negative implications should be more apt to seek out information about them, as anxiety motivates information seeking (e.g., MacKuen, Marcus, Neuman, & Miller, 2010). Information seeking should translate into a greater probability of correctly perceiving one's proximity to an energy site.

2.1.3. Media Use

Those attending to national and local news media should be more likely to correctly identify whether they live near an energy site. Numerous studies show positive relationships between news media exposure and knowledge (e.g., Neuman, Just, & Crigler, 1992). Specific to science, studies find that those attending to mainstream news sources and science information in the media know more, and believe that they know more, about science topics (Takahashi & Tandoc, 2015; Zhao, 2009; Zhao, Leiserowitz, Maibach, & Roser-Renouf, 2011). Those using local news, in particular, should be especially likely to answer proximity questions accurately because the local news should provide information about the location of these potential risks. Indeed, research shows that local coverage influences people's perceptions of local environmental factors, such as food safety (Fleming, Thorson, & Zhang, 2006).

2.1.4. Social Contact

Individuals' relevant interpersonal contacts can contribute to knowledge gaps (Tichenor, Donohue, & Olien, 1970). Interacting with knowledgeable others can increase one's own knowledge, even when one would not naturally seek out the information (e.g., McDevitt & Chaffee, 2002). Those who engage in conversations with others who are knowledgeable about local energy sites are provided additional opportunities to learn about them. Contact with employees of these industries likely exerts influence on accurate perceptions of their proximity.

H1. Those who (a) have higher science knowledge, (b) perceive greater risk, (c) use more media, or (d) know others in the field are more likely to perceive their proximity to nuclear, refinery, and fracking sites correctly.

2.2. Misperceptions About Proximity

The second line of theory suggests that these same factors may contribute to misperceiving one's proximity to energy sites. Information gleaned from personal, interpersonal, or mediated sources may introduce a perceptual bias by increasing the salience of such sites, resulting in a greater likelihood of believing one resides nearby. This effect aligns with the availability heuristic (Tversky & Kahneman, 1973; Zillmann, 2006)—judgments are influenced by exemplars that are available at top-of-mind. According to this theory, relying on exemplars available in memory leads to overrepresentations when evaluating at a later date. A parallel effect may occur in judging spatial proximity.

2.2.1. Science Knowledge

Although scientific knowledge should enhance the accuracy of perceived proximity, it also could distort perceptions of proximity due to the availability of exemplars. When asked to recall whether they live near an energy site, people may search their memory for examples of these sites and use the ease of retrieval as a proxy for determining how nearby they live. The knowledgeable are more prone to processes that occur due to availability biases, such as priming and framing effects (Chong & Druckman, 2007; Miller & Krosnick, 2000). In this context, greater science knowledge may provide more easily accessed exemplars for nuclear energy, fracking, or refineries, and thus lead to overrepresentations and greater likelihood of reporting one is nearby regardless of actual proximity.[5]

2.2.2. Risk Perception

Perceiving greater risk in energy sites also may lead people to err in judging their proximity, yet whether perceived risk should make people feel more, or less, proximate to energy sites is not theoretically clear. On the one hand, a distorted view

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[5]Similarly, individuals possessing greater science knowledge may be more likely to provide attitude-consistent (and therefore potentially incorrect) responses for certain issues (Kahan, 2012). This suggests the possibility that science-knowledgeable individuals, for instance, may be more likely to (wrongly) deny living near a nuclear site if they deem the technology to be risky. Exploratory tests of science knowledge × risk perception interactions in our models, however, show no significant effects on proximity perception. We thank an anonymous reviewer for this insight.

held by high risk perceivers is supported by psychology research showing that threats are perceptually exaggerated, and can appear closer than they actually are (Cole, Balcetis, & Dunning, 2013; Harber, Yeung, & Iacovelli, 2011). On the other hand, some work suggests that greater risk perception will be accompanied by a need to reduce and manage the cognitive dissonance it induces (Bickerstaff & Walker, 2001; Festinger, 1957; Maderthaner, Guttmann, Swaton, & Otway, 1978). Those who perceive nuclear sites to be high risk, for example, might be less likely to report living nearby to reduce (subconsciously) the level of threat they associate with these sites. Given the mixed theoretical accounts, we pose a research question about the possible distorting effect of risk perceptions.

2.2.3. Media Use

Although media exposure can increase knowledge, it can also result in misperceptions (Ecker, Lewandowsky, & Apai, 2011; Garrett, Weeks, & Neo, 2016; Kull, Ramsay, & Lewis, 2003; Nyhan, 2010; Veenstra, Hossain, & Lyons, 2014). One way media accounts may bias perception is by providing exemplars that are out of step with reality (Zillmann, 2006). For instance, local news outlets might cover a story about a *proposed* fracking site that ultimately never comes into being. Such coverage might be poorly encoded in or recalled from memory. As a result, individuals who attend to the news could erroneously believe they reside within a given range of the hypothetical fracking site. Similarly, consuming national news could lead individuals to believe mistakenly that they live closer to a site than they do. Depending on the level of attention a news consumer gives (Chaiken & Eagly, 1983; Hollander, 2014; Levy, 1978), increased salience of a type of site by way of national coverage could result in the misperception that an individual is in close personal proximity.

2.2.4. Social Contact

Finally, just as social contact can provide more opportunities to gain knowledge, social influence can also result in less accurate perceptions (e.g., Brunson, 2013). For individuals in highly clustered networks, for instance, dominant beliefs may drown out a more accurate competing view, reducing the ability of the network's members to learn and update their beliefs (Klar & Shmargad, 2016). In this study, contact with employees of certain industries may result in overin-

flated perceptions of proximity to their workplaces. Again, this account coincides with the increased availability of exemplars, and tendency toward over-representation in subsequent evaluations.

> **H2.** Those who (a) have higher science knowledge, (b) perceive greater risk, (c) use more media, or (d) know others in the field are more likely to perceive that they are more proximate to nuclear, refinery, and fracking sites than they are in actuality.
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> **RQ1.** Do risk perceptions affect the probability that people misperceive their proximity to nuclear, refinery, or fracking sites?

2.3. Proximity Beliefs Across Sites

Studies on proximity and perception are typically undertaken for single site types, and usually in limited geographic areas. For example, Cale and Kromer (2015) found that proximity to nuclear sites in North Carolina increased awareness of their presence. Cuite et al. (2016) looked at whether different evacuation messages in flood zones in Connecticut, New Jersey, and New York reduced "shadow" evacuation among those who did not actually live in evacuation zones. Giordano et al. (2010) compared individuals' actual distance and perceived distance from a single nuclear site in New York, finding that residents perceived distance differently than current emergency response planning area divisions. Finally, Howe (1988) found that perceived distance better predicted concern about living near toxic waste sites in one New York county than did actual distance. Our study advances the literature by using nationwide data to look across nuclear, refinery, and fracking sites. While providing variation, nuclear reactors, refineries, and fracking wells each fit within the traditional "technological environmental risks" paradigm. As such, we are able to be more confident in modeling the role of risk perception and other social–psychological factors in proximity perception for this broader category of risk site.

These three types of sites differ in numerous ways that could account for either accurate or distorted views of proximity and for unique relationships with the personal characteristics described above. For instance, the obtrusiveness of a site's physical structures could affect proximity knowledge. It may be easier to develop accurate proximity perceptions for highly visible nuclear reactors than for lower-profile fracking wells. As another possibility,

the frequency with which the topic is discussed in the media could influence people's awareness. Fracking, for instance, has been the topic of extensive national media coverage, while oil refineries have received less scrutiny recently. Given variations across the sites, but little existing theoretical insight about potential systematic differences, we ask a research question:

RQ2. Do correlates of proximity knowledge differ across sites?

3. METHODS

This study makes use of previously unpublished survey data from the Pew Research Center's American Trends Panel (ATP), a national, probability-based panel of adults in the United States. In total, 9,810 RDD survey respondents were invited to join the ATP and 5,338 accepted, yielding a panel acceptance rate of 54.4%. Adults who used the Internet participated in the panel via self-administered web surveys, and adults who did not participated via mail. The survey was administered in English and Spanish.

More specifically, the data employed in this study came primarily from the ATP's wave 11, with some data coming from waves 6 and 12 (depending on which wave included the necessary measures) as noted below. These waves were fielded in August and September 2014 (wave 6); June 2015 (wave 11), and August and September 2015 (wave 12). In total, 3,278 ATP members completed wave 6, 3,057 completed wave 11, and 3,095 completed wave 12. Given the response rate to the probability-based recruitment survey and those respondents who agreed to participate in the panel, the cumulative response rate for wave 6 of the panel was 3.6%, and for waves 11 and 12 was 3.3%.

3.1. Proximity Measures

Respondents ($n = 2,418$) were asked "Do you live within 25 miles of any of the following?" with options including a nuclear power plant (12.8%), an oil or coal refinery (11.8%), and a fracking site (8.3%). Researchers have employed this 25-mile threshold in studies of nuclear facilities' effects (Gamble & Downing, 1981; Goldsteen & Schorr, 1982; Marter, 1963; Walsh, 1981) and waste facilities and property values (Zeiss & Atwater, 1989), as well as to address spatial questions in areas as diverse as healthcare (Monath, Giesberg, & Fierros, 1998; Slater,

O'Mara, & Goldfarb, 2002), recreation (Long & Perdue, 1990), and wildlife management (Bellrose, 1955). The 25-mile range is also used in classifications of urban, suburban, town, or rural areas. A distance of greater than 25 miles from an urbanized area falls into the "rural" category (National Center for Education Statistics, 2006). This distance thus represents an often-used metric for proximity.

We created objective measures using the most up-to-date national databases available for the three site types. We drew GIS data for fracking wells from FracFocus's Chemical Disclosure Registry (Arthur, Layne, Hochheiser, & Arthur, 2014; Jackson et al., 2015; Zwickl, 2019), for nuclear facilities from the U.S. Nuclear Regulatory Commission, and for refineries from the Environmental Protection Agency's Facility Registry Service (see Appendices A and B of the Supporting Information for full source information). Using ArcGIS, we determined whether respondents' addresses (converted to latitude and longitude) fell within 25-mile radii of these features, and for descriptive purposes constructed dichotomous variables for objective proximity to each site type. These frequencies are reported in Table I. For our analysis, we then created a continuous objective measure for each site type. Probability of reporting one resides within 25 miles of each site by actual distance from these sites is depicted in Fig. 1 (see Fig. A1 in the Supporting Information for depiction of observed data).

3.2. Independent Variables

3.2.1. Science Knowledge

Respondents' science knowledge was measured across 12 items asked in wave 6, such as "Which kind of waves are used to make and receive cell phone calls?" and "What does a light-year measure?" Correct responses to each multiple-choice question were coded as "1" and incorrect responses as "0." We summed the responses to create a measure of science knowledge (M = 8.78, SD = 2.37).

3.2.2. Perceived Risk

In wave 12, respondents reported their perceived risk (1 = very safe, 4 = very dangerous) of living within 25 miles of a nuclear power plant (M = 2.72, SD = 0.98), an oil or coal refinery (M = 2.67, SD = 0.87), and a fracking site (M = 2.66, SD = 0.95).

Table I. Frequencies of Proximity Perception <25 Miles

	False Negative	False Positive	True Negative	True Positive
Fracking	198 (8.1%)	91 (3.8%)	2,015 (83.3%)	114 (4.7%)
Nuclear	101 (4.2%)	190 (7.9%)	1,993 (82.4%)	134 (5.5%)
Refinery	348 (14.4%)	110 (4.5%)	1,784 (73.8%)	176 (7.3%)

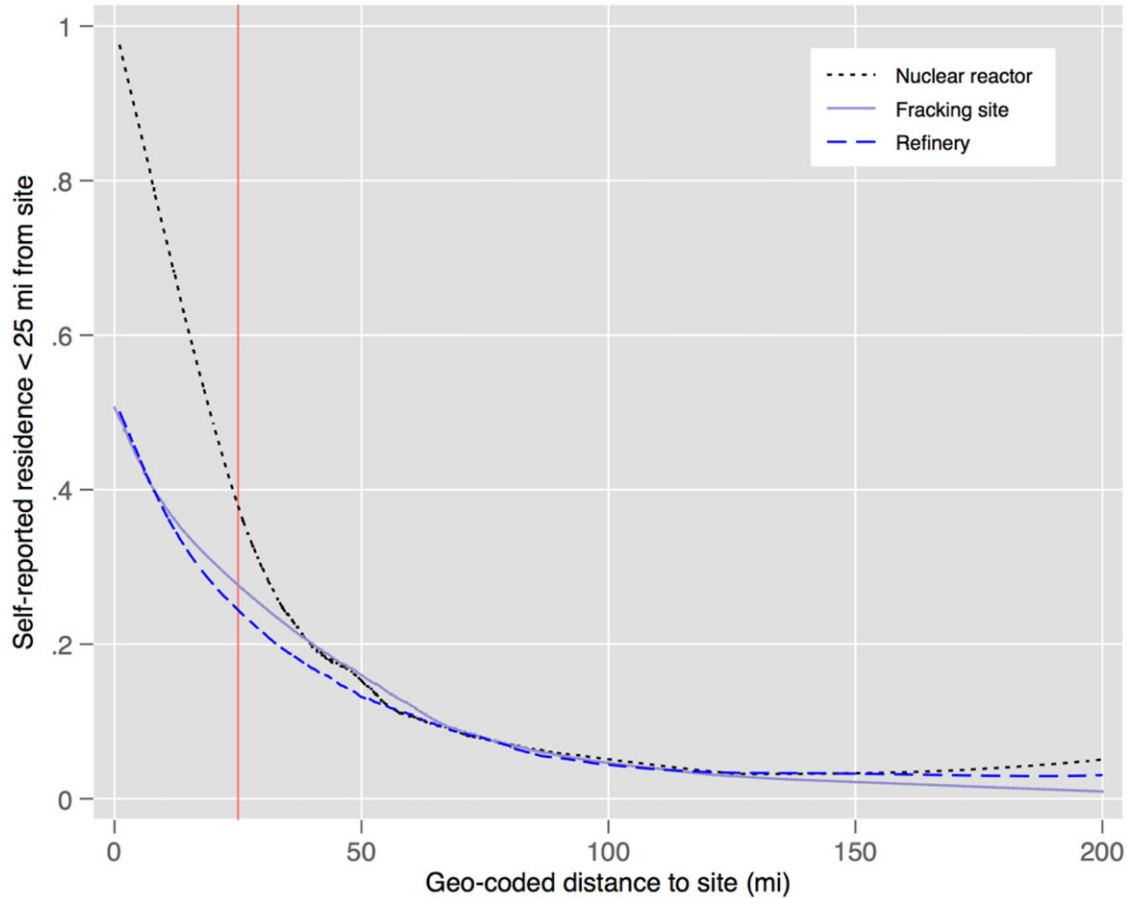*Note*: Unweighted percentages. $N = 2,418$.

Fig. 1. Self-reported proximity <25 miles by actual proximity (lowess plot).
Note: Self-reported <25-mile proximity is a binary measure.

3.2.3. News Use

To measure news use, we used a version of the program list technique recommended by Dilliplane, Goldman, and Mutz (2013). Local news use was measured as use of either local newspapers or local TV news in the past week (M = 0.75, SD = 0.43). National news use was measured as using news from any of the major networks (*ABC News*, *NBC News*, or *CBS News*) or national newspapers (*USA Today*, *The New York Times*, *Wall Street Journal*, or *Washington Post*) in the past week (M = 0.70, SD = 0.46).

3.2.4. Social Contact

To assess social contact, respondents reported whether they had any family or close friends who work in related industries: nuclear power (4%), "natural gas extraction (fracking)" (4%), and energy

(11%), which we use as a proxy for refinery industry contact.

3.3. Covariates

Age (M = 52.49, *SD* = 16.84), sex (51% female), race (8% black, 8% Hispanic), education (median = Bachelor's degree), political ideology (1 = very liberal to 5 = very conservative, M = 3.07, *SD* = 1.05), tenure at current address (a dichotomous variable, 64.8% for five years or longer), and urban (36.8%), rural (13.4%), or suburban (49.8%) residency were included as covariates.

3.4. Analysis

Hypotheses were addressed using logistic regressions estimating self-reported proximity.[6] Following previous work, we predicted people's perceptions of whether they lived within 25 miles of a site, controlling for the reality (for similar bias-modeling approaches with observational data, see Ansolabehere & Jones, 2010; Craun, 2010; Huckfeldt, 2001). There are a few reasons we take this modeling approach rather than computing a binary accuracy outcome variable. As the descriptive results detailed below show, respondents are much more accurate in their self-reports when they reside outside the 25-mile threshold than when they reside within it, and the vast majority of respondents live outside of the threshold for each site type. A binary accuracy outcome would not allow us to distinguish among true and false positives and true and false negatives. Further, computing a binary accuracy outcome variable would reduce the variance of the continuous distance measure and would prevent us from examining differences in the associations between our explanatory variables and perceived proximity across actual distance, as this would be accounted for in the accuracy term.

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[6]Most of the dependent variables were modestly correlated. Saying one lives near refinery sites was correlated with saying one lives near fracking sites ($r = 0.11$, $p < 0.001$) and nuclear sites ($r = 0.11$, $p < 0.001$). Saying one lives near fracking sites was not correlated with saying one lives nuclear sites ($r = -0.01$, $p = 0.96$). For this reason, we include a robustness check in Appendices A and B of the Supporting Information. Because our dependent variables are dichotomous, we employ multivariate probit regression, allowing a correlation between the error terms of the equations. This model produces substantively similar results. We report two divergences in Section 4 and emphasize relationships consistent in both models.

As such, self-reported proximity was modeled for each type of site, using actual proximity, science knowledge, risk perception, local news, national news, and social contact, and the interaction of each of these with actual proximity, in addition to demographic variables. Main effects of these variables, after controlling for actual proximity, indicate a distorting effect whereby the factor has an effect on whether people *think* they live nearby regardless of whether they, in fact, do. Interactions between actual proximity and each factor could indicate a boost in accuracy. If those using local news, for instance, are more likely to say that they live nearby a site when they do, and less likely to say they live nearby when they do not, then accuracy is enhanced by local news. If, however, the interaction result shows that watching local news increases perceived proximity particularly for those who do *not* live nearby, then local news would have a distorting effect. Because significant interactions could signal accuracy or distortion, we examine marginal effects to clarify the nature of the relationship.

4. RESULTS

4.1. Descriptive Results

First, we present weighted descriptive statistics concerning proximity awareness. We employ survey weights for these topline calculations (unweighted results can be found in Appendices A and B of the Supporting Information). Table II shows that between 10% (nuclear) and 22% (refinery) of Americans live near these sites. In terms of overall proximity awareness, accuracy is high. In general, Americans accurately classify their proximity to nuclear sites (90%), fracking sites (88%), and refineries (79%). However, where it matters most—among those actually residing within 25 miles of these risk sites—accuracy is significantly lower. Only 54% of Americans living within 25 miles of a nuclear site, 30% of fracking-proximal, and 24% of refinery-proximal residents responded accurately.

4.2. Hypothesis Tests

The results of each logistic regression model are shown in Table III (for main effects models, see Table A3 in the Supporting Information). We review the results for each predictor below. We first report any interactions, and in their absence, any main effects.

Table II. Proximity Awareness Descriptive Results

Site	Live Within 25 Miles (%)	Accurately Know Whether They Live Within 25 Miles (%)	Accuracy Among Those Who *Do* Live Within 25 Miles (%)
Nuclear	10	90	54
Fracking	13	88	30
Refinery	22	79	24

Note: Weighted percentages. Total $N = 2,307$.

Table III. Logistic Regression Analysis Predicting Perceived Proximity <25 Miles

	Nuclear			Refinery			Fracking		
	Odds Ratio	SE	p	Odds Ratio	SE	p	Odds Ratio	SE	p
Distance to site (miles)	0.95	0.01	0.000	0.99	0.01	0.165	0.98	0.01	0.039
Age	1.01	0.00	0.284	1.01	0.01	0.021	0.99	0.01	0.321
Female	0.89	0.14	0.461	0.65	0.10	0.005	0.80	0.15	0.234
Black	0.96	0.31	0.908	0.73	0.28	0.417	0.19	0.14	0.026
Hispanic	0.75	0.24	0.372	0.92	0.29	0.793	0.41	0.19	0.055
Education (8-point)	0.98	0.04	0.633	1.05	0.05	0.249	1.08	0.06	0.160
Ideology (5-point)	1.08	0.08	0.285	1.07	0.08	0.381	0.98	0.10	0.815
Tenure	1.11	0.19	0.523	0.86	0.15	0.375	1.02	0.22	0.907
Urban	0.85	0.13	0.310	1.00	0.16	1.000	0.70	0.15	0.089
Rural	0.48	0.14	0.012	1.09	0.27	0.728	1.64	0.39	0.039
Science knowledge (12-point)	0.94	0.06	0.311	1.14	0.06	0.012	0.97	0.06	0.684
Perceived risk (4-point)	0.57	0.07	0.000	0.76	0.09	0.028	0.58	0.09	0.000
Local news	1.87	0.56	0.036	1.38	0.37	0.228	1.25	0.41	0.505
National news	0.94	0.26	0.812	1.25	0.29	0.339	1.74	0.54	0.071
Family/friends in industry	2.91	1.05	0.003	1.85	0.57	0.047	3.06	1.08	0.001
Knowledge × Distance	1.00	0.00	0.070	1.00	0.00	0.026	1.00	0.00	0.463
Risk × Distance	1.01	0.00	0.000	1.00	0.00	0.013	1.00	0.00	0.013
Local news × Distance	0.99	0.00	0.167	1.00	0.00	0.834	1.00	0.00	0.637
National news × Distance	1.00	0.00	0.453	0.99	0.00	0.035	1.00	0.00	0.357
Family/friends × Distance	1.01	0.00	0.001	1.00	0.00	0.589	1.00	0.00	0.435
Constant	1.99	1.64	0.404	0.07	0.05	0.000	1.14	1.00	0.877
N		2,020			2,024			2,009	
McFadden's R^2		0.17			0.16			0.25	

4.3. Science Knowledge

H1(a) stated that those who live nearby and have higher science knowledge will be more likely to believe that they live near nuclear, refinery, or fracking sites.

H2(a) stated that after controlling for whether people live nearby, science knowledge will increase the chances that people believe they live near nuclear, refinery, or fracking sites.

Science knowledge had no significant effects in any of the three models.[7]

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[7]There is an interaction between science knowledge and distance for perceived refinery proximity in the logistic model, but this is not robust to the multivariate probit model specification.

4.4. Risk Perception

H1(b) stated that those who perceive greater risk will be more accurate in their beliefs about whether they live near nuclear, refinery, or fracking sites.

RQ1 asked if risk perception increases or decreases the chances that people believe they live near nuclear, refinery, or fracking sites, after controlling for whether people live nearby.

Results show that risk perception significantly interacted with actually living near a site for nuclear (Exp(B) = 1.01, $p < 0.001$), refinery (Exp(B) = 1.00, $p = 0.013$), and fracking sites (Exp(B) = 1.00, $p = 0.013$). For these types of sites, the result is in the

Table IV. Marginal Effects of Risk Perception on Perceived Proximity, Across Actual Distance

	Fracking			Refinery			Nuclear		
	dy/dx	SE	p	dy/dx	SE	p	dy/dx	SE	p
Distance (miles)	Fracking Risk = 2			Refinery Risk = 2			Nuclear Risk = 2		
5	−0.14	0.06	0.010	−0.04	0.05	0.422	−0.04	0.03	0.157
10	−0.14	0.06	0.012	−0.04	0.05	0.422	−0.04	0.03	0.154
25	−0.13	0.06	0.018	−0.04	0.05	0.420	−0.05	0.03	0.157
50	−0.12	0.06	0.029	−0.03	0.04	0.414	−0.05	0.03	0.168
75	−0.10	0.05	0.037	−0.03	0.04	0.405	−0.03	0.02	0.175
100	−0.09	0.04	0.041	−0.02	0.03	0.397	−0.02	0.01	0.177
200	−0.03	0.02	0.046	−0.01	0.01	0.439	0.00	0.00	0.183
300	−0.01	0.01	0.107	0.00	0.01	0.571	0.00	0.00	0.155
400	0.00	0.00	0.258	0.00	0.00	0.679	0.00	0.00	0.314
500	0.00	0.00	0.490	0.00	0.00	0.750	0.00	0.00	0.647
	Fracking Risk = 3			Refinery Risk = 3			Nuclear Risk = 3		
5	−0.22	0.07	0.002	−0.12	0.08	0.128	−0.13	0.04	0.001
10	−0.22	0.07	0.003	−0.11	0.07	0.125	−0.14	0.04	0.000
25	−0.21	0.08	0.008	−0.11	0.07	0.114	−0.15	0.04	0.000
50	−0.18	0.08	0.017	−0.09	0.05	0.086	−0.13	0.04	0.000
75	−0.15	0.07	0.023	−0.08	0.04	0.058	−0.09	0.03	0.001
100	−0.13	0.06	0.024	−0.06	0.03	0.041	−0.05	0.02	0.001
200	−0.05	0.02	0.022	−0.03	0.02	0.201	−0.01	0.00	0.002
300	−0.01	0.01	0.069	−0.01	0.01	0.497	0.00	0.00	0.000
400	0.00	0.00	0.234	0.00	0.01	0.655	0.00	0.00	0.144
500	0.00	0.00	0.454	0.00	0.00	0.741	0.00	0.00	0.707
	Fracking Risk = 4			Refinery Risk = 4			Nuclear Risk = 4		
5	−0.30	0.11	0.006	−0.11	0.09	0.216	−0.25	0.06	0.000
10	−0.30	0.11	0.008	−0.10	0.08	0.214	−0.26	0.05	0.000
25	−0.28	0.11	0.014	−0.10	0.08	0.202	−0.27	0.05	0.000
50	−0.24	0.10	0.023	−0.08	0.06	0.173	−0.21	0.04	0.000
75	−0.20	0.09	0.027	−0.07	0.05	0.138	−0.14	0.03	0.000
100	−0.16	0.07	0.027	−0.06	0.04	0.109	−0.09	0.02	0.000
200	−0.06	0.02	0.018	−0.02	0.02	0.212	−0.02	0.00	0.000
300	−0.02	0.01	0.057	−0.01	0.01	0.487	−0.01	0.00	0.000
400	0.00	0.00	0.232	0.00	0.01	0.648	0.00	0.00	0.128
500	0.00	0.00	0.388	0.00	0.00	0.736	0.00	0.00	0.735

Note: dy/dx for factor levels is the discrete change from the base level. Base outcome: risk = 1.

opposite direction of H1b. For example, heightened risk perceptions were related to *less* accurate proximity perceptions among those living nearby (it is important to note that risk perception is associated with misperception [false negatives] for those within close proximity, but increased accuracy for those beyond the 25-mile threshold). We report marginal effects of risk perception in Table IV.

Moving from low (1) to high (4), risk perception decreases the probability of perceived proximity by 11.8%, on average, for fracking sites. However, the effect is strongest for those closest to fracking sites; high risk perception decreases probability of perceived proximity for those within 25 miles by 28–30%. The relationship gradually wanes as actual distance increases. Similarly, moving from low to high risk perception for nuclear sites decreases probability of perceived proximity by about 17.8%, on average, and again the relationship is stronger nearest the risk site. High risk perception decreases the probability of perceived proximity by 25–27% for respondents living within 25 miles of a nuclear reactor.

Again, the relationship gradually wanes with actual distance. Refinery risk perception follows a similar pattern, but its effects are smaller.[8] Moving from low to high perceived risk decreases the probability of perceived proximity by 6.8% on average (refinery risk perception displays some slight nonlinearity, with a larger difference, 7.5%, obtained by moving from 1 to 3 on the four-point scale). High risk perception decreases the probability of perceived proximity by 10–12% among those living within 25 miles of a refinery site. Probability of reporting proximity across actual distance and perceived risk for each site type is depicted in Fig. A2 in the Supporting Information.

4.5. Media Use

H1(c) stated that those who live nearby and use more media will be more likely to accurately believe that they live near nuclear, refinery, or fracking sites.

H2(b) stated that after controlling for whether people live nearby, media use will increase the chances that people believe they live near nuclear, refinery, or fracking sites.

Our results show a main effect of local news for refinery site proximity perception (Exp(B) = 1.46, $p = 0.048$), supporting the availability-misperception hypothesis. National news use had no consistent effects across models.[9]

4.6. Social Contact

H1(d) stated that those who live nearby and know others in the field will be more likely to believe that they live near nuclear, refinery, or fracking sites.

H2(c) stated that after controlling for whether people live nearby, knowing others in the field will increase the chances that people believe they live near nuclear, refinery, or fracking sites.

The interaction of actual proximity and social contact was significant in the case of nuclear sites. We report marginal effects of social contact in

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[8]In examining these effects on self-reported proximity, it is worth recalling that respondents were much more aware of proximal nuclear facilities (57% of proximal respondents) than proximal fracking (37%) or refinery sites (34%).

[9]There is an interaction of national news use and distance for perceived refinery proximity in the logistic model, but this is not robust to the multivariate probit model specification.

Table V. Marginal Effects of Social Contact on Perceived Proximity to Nuclear Sites Across Actual Distance

Distance (miles)	dy/dx	SE	p
	Nuclear Contact = 1		
5	0.14	0.05	0.008
10	0.15	0.05	0.005
25	0.17	0.06	0.002
50	0.16	0.06	0.008
75	0.11	0.05	0.022
100	0.07	0.03	0.031
200	0.01	0.01	0.025
300	0.01	0.00	0.015
400	0.00	0.00	0.150
500	0.00	0.00	0.703

Note: dy/dx for factor levels is the discrete change from the base level. Base outcome: contact = 0.

Table V. The average marginal effect of social contact with nuclear industry employees on the probability of perceived proximity is an increase of 14.8%. Although strongest among respondents living within 25 miles of a nuclear site, social contact's marginal effect is still substantial at 50 miles (16%), 75 miles (11%), 100 miles (7%), and beyond. This suggests that contact is associated with more accurate responses from proximal respondents, but inaccurate responses for more distant respondents, up to a range of 300 miles.

For refineries and fracking, the interaction between actually living near an energy site and social contact was not significant. The main effects of having family or close friends working in the industry (refinery model: Exp(B) = 1.56, $p = 0.029$; fracking model: Exp(B) = 3.69, $p < 0.001$), however, were significant. Here, contact with employees of the industry was also associated with increased chances of believing that one lives nearby, controlling for whether that is actually the case.

5. DISCUSSION

This study combined national survey responses and GIS data to assess the accuracy of the public's perceived proximity to several energy sites. We examined a range of potential sources of increased accuracy or misperception, including both orientations to information (science knowledge and risk perception), and access to sources of information (news use and social contact). We tested whether these factors increase awareness and/or drive misperception of individuals' proximity to energy sites.

Risk perceptions were related with proximity perceptions for each of the sites examined. The more risk one perceived, the less likely one was to report living near an energy site. For nuclear sites, fracking wells, and refineries, those who actually did live near these sites were more likely to say that they did so when they believed that the sites were safe. Among those who did not live nearby, risk was related to lower perceptions of proximity as well. The relationships show that the riskier individuals see these sites to be, the less likely they are to believe that they live nearby. This is in line with a dissonance-reduction account (Festinger, 1957)—when faced with the conflict between believing that a site is risky and living near a site, one way to resolve the dissonance is to adjust one's belief about how nearby the risk is. This runs counter to the idea that anxiety should lead to information seeking uncovered in research in political contexts (MacKuen et al., 2010). It is possible that the difference occurs because science is a different domain than politics. Another possibility is based on the extended parallel process model, which suggests that fear unaccompanied by information about how to absolve the threat can be paralyzing (Witte, 1992, 1994). Feeling that the sites are risky, and without an ability to move out of harm's way, people may distort their perception of proximity in response. In politics, people may have a greater sense of efficacy because they can participate in a range of actions, like voting for different candidates.

Social contact was also consistently related to the proximity perceptions that we analyzed. For all three energy sites we evaluated, social contact was significantly correlated with perceived proximity. We find that social contact increased perceptions that one lives near energy sites, regardless of whether one does in fact live nearby.

There is little evidence of a role for science knowledge, and only inconsistent evidence regarding the possible role of media use in proximity perception, potentially due to measurement issues. Science knowledge was only associated with perception of proximity refineries, in this case leading to overestimation. The null effects of science knowledge, despite a robust literature suggesting that domain-specific knowledge should predict other types of knowledge, are noteworthy. Prior literature has often assessed whether domain-specific background knowledge predicts knowing current events in the same domain (e.g., Price & Zaller, 1993; Zaller, 1992). Proximity knowledge may be a different form of knowledge. Perhaps it would be better predicted by other types of geographic knowledge than science in general. Future research should analyze whether spatial awareness is a stronger predictor of proximity perceptions than science knowledge. In any event, general science knowledge may be a poor proxy for the sort of domain knowledge that matters for perceived proximity to technological–environmental risk sites. Similarly, in most instances, use of local and national news media did not relate to proximity perceptions. The sole exception to this pattern was the role of local news in predicting misperceived proximity to refinery sites. Our measures of news use are broad and may inadequately capture actual exposure to relevant news content (e.g., Besley & Oh, 2014).

This study's strengths include its national scope, variety of energy sites analyzed, and novel tie-in of geospatial data. This study analyzed three different risk site types on a national scale—an advancement over studies that focused on a single risk site. Not surprisingly, there is site-by-site variation in public awareness that could be explained by multiple factors. Although differences by site poses a challenge to further refinements of a broad theory about proximity awareness, some trends we detect are consistent, namely, those of risk perception and social contact. In terms of biased perception, then, at least two different mechanisms appear to be in play. Most broadly, the availability heuristic may account for false-positive reports associated variously with news use, and most consistently, social contact with employees. In addition, risk perception's negative association with reported proximity suggests dissonance avoidance can skew perceptions of vicinity. Building on our findings regarding risk perception, future work may explore other dissonance-related sources of distortion in perceived proximity—such as support for alternative energy or fear of terrorism targeted at nuclear sites.[10]

There are several limitations that warrant discussion. Importantly, as with any observational study, we cannot make causal claims about our findings. Future work can address some of these relationships, such as those concerning risk perception or local news, through manipulations via experimental design. Similarly, examining the actual content of the information sources analyzed here can shed light on the underlying processes. In terms of measurement, in addition to the issues with domain knowledge and news use discussed above, there may be some small differences between the energy sites in the

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[10]We thank the anonymous reviewer for these points.

last-available national database and the reality on the ground. Finally, our proximity measure used an admittedly arbitrary 25-mile radius. This specific distance may be more or less relevant depending on the nature of the site, but nonetheless provided a consistent baseline across models.

Despite these limitations, our findings show that there are several key routes through which strategic communication can influence residents' proximity awareness. Ultimately, whether the ideal route is topical (e.g., via local news or discussion of relevant risk) or through outreach (e.g., contact with industry employees) may depend on the nature of the site. Future work can provide greater depth regarding how the public makes sense of individual energy operations. Together with the work reported here, this could inform message design for evacuation warnings (Cuite et al., 2016), water treatment, or other health-related precautions (Kourniotis, Kiranoudis, & Markatos, 2001), depending on the site. Finally, leveraging these more effective dissemination channels for proximity information can help residents make home owning, family planning, and other decisions in line with their underlying preferences. That said, such work should also examine the effects of increasing proximity awareness on support for (and bases of support for) the energy sites we focus on, complementing work that shows reduced psychological distance is associated with less reliance on abstract considerations when forming opinions on fracking (Clarke et al., 2016).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table A1. Descriptive Statistics for Independent Variables and Covariates

Table A2. Multivariate Probit Analysis Predicting Perceived Proximity

Table A3. Logistic Regression Analysis Predicting Perceived Proximity (Main Effects Only)

Table A4. Proximity Awareness Descriptive Result (Unweighted)

Fig. A1. Self-reported proximity <25 miles by actual proximity (lowess plot with jittered observed data).

Fig. A2. Contour plot depicting probability of reporting <25 miles proximity across actual distance and perceived risk.