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ORIGINAL ARTICLE

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Abstract
Lead exposure is a persistent environmental hazard that poses risks to human health. But motivating protective action is challenging with this low visibility hazard whose health effects are often subtle and chronic. Higher risk perception is generally associated with taking protective measures, so public health efforts prioritize risk messaging. Yet, little is known about perceptions of lead exposure risk among the U.S. public. Using cross-sectional data from a national survey of 1035 U.S. residents, we measured the role of trust in government management of lead and subjective knowledge about lead as predictors of perceived risk of lead exposure, controlling for demographic and environmental factors. We also assessed if subjective knowledge moderated the relationship between trust and perceived risk. Our results reveal positive relationships between trust in government management of lead, subjective knowledge about lead, and risk perception, which we attribute in part to the important role government agencies play in secondary prevention, or communicating the risks of environmental lead exposure. We also found that younger people and people living in a house built before lead paint regulations passed in 1978 perceived higher lead risks. Our findings suggest that general communication about lead risks should aim to increase people's subjective knowledge in a consistent and balanced way that improves trust in government messengers.

KEYWORDS
environmental health, lead exposure, perceived risk, subjective knowledge, trust in government

1 | INTRODUCTION

One out of two people alive in the United States in 2015 was exposed to harmful levels of lead (Pb) in childhood (McFarland et al., 2022). Used historically in paint, gasoline, and pipes, lead is a potent neurotoxin with additional effects throughout the human body (Wani et al., 2015). Epidemiological research has documented deficits in cognitive ability and fine motor skills resulting from childhood lead exposure (Bellinger, 2008) that are likely associated with chronic and late-age conditions such as cardiovascular disease and dementia (Lanphear et al., 2018; Reuben, 2018; Vig & Hu, 2000). Because children are particularly vulnerable to detrimental health effects of lead exposure (Meyer et al., 2008), the U.S. Centers for Disease Control (CDC) concluded in 2012 that there is no safe level of lead exposure in children (Vorvolakos et al., 2016). While new sources of lead in the environment have declined in the United States during the past 50 years due to federal regulation (e.g., primary prevention of lead exposure through removal) (Dignam et al., 2019), lead persists as an environmental pollutant and public health concern (Boskabady et al., 2018; Lanphear et al., 2018; O'Connor et al., 2018). For instance, the U.S. Food and Drug Administration continues to find lead in baby food samples, and the U.S. Consumer Product Safety Commission regularly issues recalls of consumer items containing lead (Dignam et al., 2019). The continued presence of lead in the environment requires secondary prevention, or providing detection programs such as blood screening and encouraging individual action to reduce lead exposure through communication campaigns (Ettinger et al., 2019). But motivating action is challenging with this low visibility hazard whose health effects are often subtle and chronic (Binns et al., 2004; Cooper et al., 2021; Lyytimäki et al., 2011; Meyer et al., 2008; Triantafyllidou & Edwards, 2012).

Recent crises have elevated coverage of lead exposure in the media. Flint, Michigan garnered sustained national attention after dangerous lead levels were revealed in the public water supply (Butler et al., 2016). Subsequent investigations have found dangerous lead levels in other cities' drinking water (McCormick & Andrade, 2022; Wines & Schwartz, 2016). Government responses to these crises were criticized in high-profile articles as insufficient. For instance, while former U.S. Environmental Protection Agency (EPA) Administrator Scott Pruitt declared a "war on lead" in 2018, he simultaneously undermined the agency's ability to consider scientific studies demonstrating the threats of lead in rulemaking (Wittenberg, 2018). Despite media attention, a 2019 study showed that U.S. residents rated lead-related issues as less concerning relative to other environmental health issues, and childhood lead poisoning was least frequently included among respondents' top health concerns affected by environmental issues (Shin et al., 2019). Risk perception is an important precursor to protective action in many contexts (Brewer et al., 2004). Understanding knowledge and perceptions of lead exposure risk across multiple subpopulations in the United States after several years of national media attention may reveal both theoretical factors associated with perception of this specific risk and opportunities for improved public interventions. Though half of the U.S. population has been exposed to lead, research has more frequently focused on specific subgroups including women of child-bearing age, individuals working in certain hazardous occupations, and residents of mining communities (Cooper et al., 2020; Klemick et al., 2020; Vorvolakos et al., 2016). Yet, communicating the risk of and preventing lead exposure is a societal concern (Griffin & Dunwoody, 2000). For example, routine blood lead level testing in all children can aid in early detection of sources of lead in or near a child's home (Boreland & Lyle, 2008).

Perceptions of risk are shaped by attributes specific to the risk itself, including its newness, uncontrollability, and catastrophic potential (Slovic, 1987). Risks associated with industrial production, like lead exposure, tend to be complex, technical, and difficult for the public to understand (Beck et al., 1992). When people feel uninformed about a risk such as lead exposure, they may base their judgement of risk on how much they trust risk management entities to assess and mitigate risks and communicate relevant information. Some research suggests that trust in risk management authorities has an important influence on risk perception when an individual has low knowledge about the risk (Siegrist & Cvetkovich, 2000). However, this relationship is context specific (Viklund, 2003) and has not been tested with respect to lead exposure risk in the U.S. population. Other variables associated with risk perception include individual characteristics and the social and cultural context related to the hazard (Harclerode et al., 2016; Masuda & Garvin, 2006). In this study, we use data from a national survey of 1035 U.S. residents to test the influence of trust and subjective knowledge on perceived risk, and whether subjective knowledge moderates the relationship between trust and perceived risk, as well as the effects of sociodemographic characteristics. Understanding perceived risk of lead exposure, and the factors that underly those perceptions, can be applied to improve communication efforts between the government, academics, and the public, inform new public policies, and anticipate public responses to future health crises (Slovic et al., 1982).

2 | LITERATURE REVIEW AND HYPOTHESES

2.1 | Trust in government management of lead

Trust is an influential predictor of risk perception when time, knowledge, and motivation are limited (Han et al., 2017; Visschers & Siegrist, 2008; Wachinger et al., 2013). When people are unable to deliberatively evaluate a risk, their perception of risk may instead be influenced by the extent to which they trust the entities responsible for managing the hazard (Earle & Cvetkovich, 1995; Siegrist & Cvetkovich, 2000). Trust in government management of a risk is a complex construct usually characterized with multiple dimensions (Poortinga & Pidgeon, 2003; Renn & Levine, 1991). In a study of five environmental and technological risks, Poortinga and Pidgeon (2003) established two primary dimensions: general trust, which is concerned with a range of trust-related issues including perceived competence, care, and fairness; and skepticism, which reflects a skeptical view of government, including industry influence and fact distortion. A subsequent study testing both dimensions found that most variation in the trust in government construct was explained by general trust items (Poortinga & Pidgeon, 2006). We thus use a general trust construct in this study because of its larger explanatory power and because the issues included in the construct are most relevant to government management of the lead risk (i.e., perceived competence is important for trust in primary prevention of exposure, and perceived care is relevant to the effectiveness of secondary prevention or communication of the risk).

Past studies on the relationship between trust in a managing entity and risk perception suggest the relationship is context specific. In a review of existing literature on trust and risk perception, Siegrist (2021) concluded that the importance of trust varies by hazard and respondent group. Viklund (2003) examined the relationship between trust and perceived risk across four European countries. There was an overall negative relationship between trust and perceived risk in the study, but that relationship varied by country and the type of risk (for instance, perceptions of nuclear risks were more influenced by trust than non-nuclear risks). The relationship between risk perception and trust in a public entity may change when the entity's role is to communicate information regarding individual or collective behaviors. This question has been explored recently in the context of the COVID-19 pandemic. Jeong and Kim (2023), in a survey study of South Koreans, found a significant positive correlation between trust in government action on COVID-19 and risk perceptions related to COVID-19. They further found through moderated mediation analysis that for people with high trust in government, risk perception was more strongly associated with information seeking behaviors. In a non-health context, Kulin and Johansson Sevä (2021), analyzing European Social Survey data from 2016, found that trust in what they call impartial government entities (e.g., the legal system, the police, bureaucracy; compared to partial entities, e.g., elected politicians) was positively correlated with climate change worry.

Because the influence of trust on risk perception varies by context, we assess this relationship with respect to U.S. residents' trust in the government's management of lead risks. The individuals and institutions responsible for lead risk management are not personally known to most Americans, and this socially distant relationship can affect levels of trust (Siegrist, 2021). In the case of secondary prevention, which is most important for avoiding exposure to dispersed environmental lead contamination, entities such as public health agencies seek to raise awareness of exposure risk and ideally influence personal protective behaviors. Government communications about lead tend to focus on the importance of individual awareness and encourage personal protective behaviors. For instance, the National Lead Poisoning Prevention Week Information Kit, a document co-created by the US EPA, CDC, Department of Housing and Urban Development, and Department of Health and Human Services, conveys the key messages "Get the Facts; Get Your Child Tested; Get Your Home Tested" (US EPA, 2022). It also emphasizes the risk of lead exposure, recommending "lead risk assessment" for homes built before 1978 and blood lead tests for children "living in high-risk areas." Descriptions of primary prevention activities by the government are absent in the document. Due to the centrality of the government's risk communication role promoting self-protective behavior, we expect that when someone has high trust in government on the issue, they will also perceive a higher risk from lead exposure.

H1 Trust in government management of lead will be positively associated with the perceived risk of lead exposure.

2.2 | Subjective knowledge of lead

Subjective knowledge refers to an individual's perception about their own understanding of a topic, whereas objective knowledge reflects the accurate information an individual possesses (Carlson et al., 2009). Subjective knowledge is often associated with subsequent attitudes, beliefs, and behaviors related to environmental risks (Glanz et al., 1997; Liu & Jiao, 2018). Such associations are based on the notion that people who are knowledgeable about an issue, or perceive themselves to be knowledgeable, may be more likely to engage (Frewer et al., 1994). In the present study, we focus on subjective knowledge. While measurements of subjective knowledge can be unreliable if misestimated by an individual (Stoutenborough & Vedlitz, 2014), the accuracy of their assessment is less important than the extent to which the individual believes their knowledge of an issue to be sufficient (Frewer et al., 1994). We did not measure objective knowledge for this study because objective knowledge has been less consistently predictive of attitudes and behaviors than subjective knowledge (Ellen, 1994).

We explore subjective knowledge in relation to the perceived risk of lead exposure because the relationship appears context specific. Focusing on industrial-created hazards, Zhu et al. (2016) investigated residents living adjacent to a nuclear power plant under construction in China. They found that the higher the residents perceived their knowledge to be, the greater their perceived risks of nuclear power. In contrast, Grasmück and Scholz (2005) studied people living close to an area of heavy metal-contaminated soil and found that participants who self-assessed their knowledge as higher perceived the risk of heavy metal exposure to be lower. Because the 2005 study focused on residents of an area with a long history of contamination, the authors point out that the relationship may have been different if the risk was less understood. They also suggest that because their participants live close to a known risk, they may be using "dissonance-reducing heuristics," or rating the risk lower as a coping mechanism. Media attention to lead exposure risks in the United States is relatively recent, as highlighted in the introduction. Thus, we did not expect a general population to have developed the same dissonance-reducing heuristics as a population with a lifetime of experience with a known risk.

H2 Subjective knowledge of lead will be positively associated with the perceived risk of lead exposure.

Subjective knowledge can play a moderating role in the relationship between trust and perceived risk (Earle & Cvetkovich, 1995; Luhmann, 2018; Siegrist & Cvetkovich, 2000). Siegrist and Cvetkovich (2000) empirically tested these relationships across 25 different hazards using correlation analysis. The authors found that when respondents felt more knowledgeable about a hazard, there was a lower correlation between risk and trust in government regulation of a hazard, and most correlations were negative. With respect to primary prevention of lead, we might expect a similar finding because respondents with higher subjective knowledge can make up their own mind about whether the government is adequately removing the lead hazard. However, because secondary prevention is so important for lead risk management, communication and monitoring effectiveness may be a more important driver of the relationship between trust, subjective knowledge, and risk. Following Jeong and Kim (2023), we expected that when someone trusts the government as a source of information about lead risk, they will also increase their knowledge and, following government information, increase risk perception.

H3 Subjective knowledge of lead will moderate the relationship between trust in government management of lead and perceived risk of lead exposure such that individuals who perceive themselves to be more knowledgeable about lead will also show a positive relationship between trust and risk perception.

2.3 | Additional influences on perceived risk of lead exposure

We sought to examine the influence of several demographic and environmental variables on perceived risk of lead exposure. We included (1) age, (2) gender, (3) race and ethnicity, (4) educational attainment, (5) household income, and (6) political ideology. Previous studies have identified age, educational attainment, and gender as factors influencing perceived risk (Bickerstaff, 2004; Casey & Scott, 2006; Flynn et al., 1994; Haltinner & Sarathchandra, 2021). Non-White individuals often perceive greater risk from environmental exposures (Johnson, 2002; Macias, 2016). Income was found to significantly predict perceived risk of lead exposure in one study such that lower income is associated with increased concern (Harclerode et al., 2016), but the relationship is different in other studies of environmental concern (e.g., Shen & Saijo, 2008). Lastly, political conservatism is generally associated with lower levels of perceived risk of exposure to contamination (Mayer et al., 2017).

We also include contextual factors specific to lead exposure: presence of children under three years old in the household and living in a pre-1978 residence. Children under the age of three are at greatest risk for lead poisoning and especially susceptible to adverse health outcomes (Schnur & John, 2014). Older housing has also been identified as a key indicator of increased lead exposure (Jacobs et al., 2002). Although the use of lead in residential paint was banned in 1978, individuals living in a home built prior to 1978 may still be exposed to lead. We expected that respondents who live in a pre-1978 home and who have at least one child under the age of three would perceive greater risk from lead exposure.

3 | METHODS AND MATERIALS

3.1 | Survey development and implementation

Study procedures were approved and certified as exempt by the University of Idaho Institutional Review Board (#19-159). Three experts in environmental risk research and a group of eight non-experts pretested the initial survey instrument. The feedback provided from this preliminary review informed several revisions to the instrument to improve clarity and reduce measurement error prior to pilot testing (Wardropper et al., 2021). The survey was then pilot tested with 100 respondents through Amazon's Mechanical Turk to assess the feasibility of the overall study procedures, including sampling, recruitment, data collection, and analysis (Edgar et al., 2016; Ruel et al., 2016). No significant changes were made to the survey following the pilot test as we were satisfied with the performance of the instrument.

We distributed the final survey instrument online from December 2020 to January 2021. Respondents were recruited using an opt-in panel coordinated by the company Qualtrics. Eligible respondents were those at least 18 years of age and residents of the United States. Respondents received a monetary incentive directly from independent panel providers, although the exact amount awarded was not disclosed to us by Qualtrics, as per their panel company policies. We requested equal quotas for age, gender, and U.S. region (Northeast, Midwest, South, and West) (Table 1). The age quota was not proportionately filled due to insufficient panel numbers of people younger than 25 and older than 65. We also requested oversampling of non-White populations, aiming for 15% each of four categories: Black/African American, American Indian/Alaska Native, Hispanic/Latino, and other races/ethnicities including Asian, Native Hawaiian/Pacific Islander, and biracial/multiracial. While random sampling techniques are the preferred method for achieving representative samples (K. Yang & Banamah, 2014), sampling error can be reduced if the quota variables are tailored to the study (Terhanian et al., 2016). Age and gender have been shown to influence perceived risk across a number of different environmental and technological risks (Davidson & Freudenburg, 1996; Harclerode et al., 2016), which is why both variables were included in our quota. We created a quota for region to assess the variety of lead hazard perspectives across the United States, and to increase responses from less populated regions. Our quotas across races and ethnicities were in place first because survey researchers have struggled to adequately represent minority populations in survey research for decades (Herzing et al., 2019; McGraw et al., 1992; Ofstedal & Weir, 2011). Second, because low-income and minority populations are disproportionately affected by lead exposure (Muller et al., 2018; Whitehead & Buchanan, 2019) and an aim of our broader research project was to examine differences in perceptions of lead across multiple racial and ethnic categories.

3.2 | Measures

The three primary study variables were measured using a five-point unipolar scale, and response labels were tailored to each item. We used unipolar scales to avoid forcing respondents to consider between two contrasting concepts (e.g., agree and disagree) (Alwin et al., 2018). We also chose to use a five-point scale because studies suggest that it can result in higher response quality than seven- or eleven-point scales, can minimize respondent burden, and is most appropriate for use with unipolar response categories (Babakus

TABLE 1 Demographic characteristics of survey sample ($n = 1035$), compared to U.S. population.

Characteristic	Sample Mean (SD) (frequency)	U.S. population[a]
Age (median)	46.1 (16.9)	38.5
18–24	12.9% (133)	9.1%
25–44	38.3% (396)	26.7%
45–64	31.1% (322)	25.3%
65+	17.8% (184)	16.5%
Gender		
Female	50.2% (520)	50.8%
Male	49.8% (515)	49.2%
Race/ethnicity		
White	37.7% (391)	60.1%
Black or African American	17.7% (183)	13.4%
American Indian or Alaskan Native	16.1% (167)	1.3%
Hispanic or Latino	13.9% (144)	18.5%
Asian	6.4% (66)	5.9%
Native Hawaiian or Pacific Islander	4.5% (47)	0.2%
Biracial or multiracial	3.7% (38)	2.8%
Highest education		
Advanced degree	17.9% (185)	9.7%
College degree (2 or 4 years)	36.7% (380)	24.8%
Some college but no degree	24.3% (252)	13.4%
High school graduate	18.9% (196)	21.4%
Less than high school degree	2.1% (22)	7.3%
Occupational status		
Working full-time	50.2% (520)	–
Working part-time	11.3% (117)	
Student	5.5% (57)	
Unemployed	5.5% (57)	
Retired	18.5% (191)	
Homemaker	5.8% (60)	
Other	3.2% (33)	
Approximate household income (median)		$68,703
Less than $20,000	12.1% (125)	–
$20,000–$49,999	25.0% (259)	
$50,000–$79,999	30.6% (317)	
$80,000–$99,999	12.7% (131)	
$100,000–$119,999	7.1% (74)	
$120,000 or more	12.5% (129)	
Region[b]		
Northeast	20.9% (216)	17.1%
Midwest	24.0% (248)	20.8%
South	28.8% (298)	28.3%
West	26.4% (273)	23.9%

[a]2019 American Community Survey.
[b]Northeast includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, and Pennsylvania. Midwest includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. South includes Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. West includes Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

& Mangold, 1992; Krosnick, 2018). Our analysis included the survey items below (full item wording for the three primary study variables can be found in Table 2). Tests of measure reliability are described in the Statistical Analysis section.

3.2.1 | Perceived risk of lead exposure

For our regression analysis, we measured perceived risk, the dependent variable, as a multidimensional variable composed of four sub-constructs including affect, perceived exposure, perceived severity, and perceived susceptibility. These items were adapted from two recent studies seeking to validate a multidimensional and broadly applicable measure of perceived risk (Walpole & Wilson, 2020; Wilson et al., 2019). Walpole and Wilson (2020) found that a four-dimensional model of risk perception including affect, perceived severity, perceived probability, and perceived susceptibility had a good fit (compared to one-, two-, and three-factor models) across multiple hazards. For the first construct, affect, we asked respondents to consider several emotions they may experience when they consider being exposed to lead. For perceived exposure, we asked respondents to consider the likelihood and frequency of being exposed to lead in the next year. For perceived severity, we requested respondents' consideration of the severity of impacts if exposure were to occur. For the fourth construct, perceived susceptibility, we asked about respondents' perception of their risk of experiencing negative impacts if exposed to lead. All 17 individual items were measured on a unipolar scale from 1 to 5, but the exact wording was tailored to each item depending on the concept being measured. For example, to answer the question "How concerned are you (if at all) about the potential negative effects of lead exposure?", response options ranged from 1 = "not at all concerned" to 5 = "extremely concerned." All items were averaged for each respondent to create a composite measure of perceived risk. This approach to constructing a multidimensional risk variable is commonly used in survey-based risk studies (e.g., Matthew et al., 2015; Rosen & Kostjukovsky, 2015; Z. J. Yang, 2016).

3.2.2 | Trust in government management of lead

Trust was measured using items adapted from Poortinga and Pidgeon (2003) that are theorized to be related to general trust, including competency, care, fairness, and openness. Respondents were asked to consider these trust-related concepts specifically as they pertain to the government's management of lead exposure risks in the United States. Each item was measured on a unipolar scale from 1 to 5 and tailored to the specific trust-related concept. As with perceived risk, a composite trust score was created for each respondent by averaging eight items.

3.2.3 | Subjective knowledge of lead

Eight items were used to determine a respondent's subjective knowledge. The first item considered the effects of lead on the human body, and the second item asked respondents to compare their level of knowledge about the effects of lead on the human body compared to other people. The remaining six items asked about level of knowledge on effects of lead on the environment, effects on wildlife, sources of lead, how lead enters the human body, how to prevent lead exposure, and laws and regulations about lead. Respondents answered all items on a response scale from 1 = "not at all knowledgeable" to 5 = "extremely knowledgeable." The eight items were averaged to create an individual subjective knowledge score.

3.2.4 | Sociodemographic characteristics

Six sociodemographic items were included in the analysis due to their theorized influence on perceived risk (Table 1). Survey respondents reported their gender (0 = "male," 1 = "female," prefer not to answer [not included in analysis]), age (continuous; calculated from year of birth), race and ethnicity (White alone, Black or African American, American Indian or Alaskan Native, Asian, Native Hawaiian or Pacific Islander, Hispanic or Latino, and Biracial or Multiracial), level of education (from no high school degree to advanced degree), income level (from less than $20,000 to greater than $120,000), and political ideology (from 1 = "strongly conservative" to 5 = "strongly liberal"; dummy coded 1 = "liberal," 0 = "not liberal"). We included five racial and ethnic groups, with Asian, Native Hawaiian or Pacific Islander, and Biracial or Multiracial respondents in one group. Education was recoded where 1 = "at least college degree" and 0 = "no college degree." Income was treated as continuous.

3.2.5 | Environmental factors

We included two items to measure environmental factors related to lead which we believed may influence perceptions of lead exposure risk. Respondents were asked to report if there were children in the home (0 = "no," 1 = "yes"). If "yes" was selected, they were prompted to report the age of their youngest child. We also asked respondents if their place of residence was built prior to 1978 (0 = "no", 1 = "yes"). One hundred and twenty-two respondents were unaware if their place of residence was built prior to 1978. These responses were treated as "no" for this analysis.

3.3 | Statistical analysis

We used IBM SPSS Statistical Software (Version 28) to analyze the survey data. Descriptive statistics (means,

TABLE 2 Means, standard deviations, and Cronbach's alphas for the primary study variables: Perceived risk of lead exposure, trust in government management of lead, and subjective knowledge about lead.

Scale	Mean (SD)	α
Perceived risk of lead exposure (15 items)	2.95 (0.86)	0.92
Affect	3.11 (0.33)	0.93
How concerned are you (if at all) about the potential negative effects of exposure to lead?		
When you think about being exposed to lead, to what extent do you feel fearful?		
When you think about being exposed to lead, to what extent do you feel anxious?		
When you think about being exposed to lead, to what extent do you feel worried?		
Considering any potential effects that being exposed to lead might have on you personally, how concerned are you about exposure to lead?		
Considering any potential effects that being exposed to lead might have on others, how concerned are you about exposure to lead?		
Exposure[a]	2.67 (0.58)	0.77
In the coming year, how likely is it that you will be exposed to lead where you live?		
How often are you exposed to lead where you live?		
Perceived severity	2.97 (0.10)	0.89
If you were exposed to lead, how severe of an impact would it have on you personally?		
How severe are the impacts of lead exposure to you?		
If you were exposed to lead, how devastating would the impacts be?		
Perceived susceptibility	2.94 (0.24)	0.88
If you were exposed to lead today, how likely is it that you would experience negative impacts?		
How likely is it that you would be negatively impacted if exposed to lead?		
How likely is it that your family would be negatively impacted if exposed to lead?		
How likely is it that your property would be negatively impacted if exposed to lead?		
Trust in government management of lead exposure risks[b] **(eight items)**	3.09 (0.68)	0.92
How would you rate the government?		
How competent is the government?		
How skilled are the people who work for the government?		
How likely is the government to act in the public interest?		
How likely is the government to listen to concerns raised by the public?		
How likely is the government to listen to what ordinary people think?		
How fair is the government's decision-making process?		
How willing is the government to provide all relevant information to the public?		
Subjective knowledge about lead (eight items)	2.69 (10.06)	0.95
How would you rate your own knowledge about the impact of lead on the human body?		
Compared to other people, how would you rate your own knowledge about the impact of lead on the human body?		
How knowledgeable do you think you are about the following issues related to lead:		
Effects on the environment		
Effects on wildlife		
Sources of lead		
How lead enters the human body		
How to prevent lead exposure		
Laws and regulations about lead		

[a]All items included stem, "With respect to managing lead risks."
[b]Spearman–Brown coefficient reported because it is a more appropriate measure of reliability for a two-item factor.

frequencies, and standard deviations) for the independent variables were first calculated to characterize the sample. We conducted a one-way analysis of variance (ANOVA) to compare the effect of race and ethnicity on perceived risk of lead exposure and establish the appropriate number of race/ethnicity groups to include in our model, followed by a Tukey's HSD test for multiple comparisons. For perceived risk and general trust in government, we performed exploratory factor analyses (EFA) to assess the variable structure. The EFAs were performed using a maximum likelihood extraction method with a direct oblimin rotation due to the expected correlation between the survey items (Costello & Osborne, 2005). We calculated the Cronbach's alpha values for risk, trust, and subjective knowledge as a measure of internal reliability with a threshold of ≥0.7 (Santos, 1999). We also calculated the Spearman–Brown coefficient for the exposure construct within risk perception (as opposed to Cronbach's alpha) because it is a more appropriate metric of reliability for two-item measures (Eisinga et al., 2013). Next, we performed confirmatory factor analysis using maximum likelihood estimation for the perceived risk and general trust variables to test the fit of the factor structure (Olsson et al., 2000), using a suggested minimum threshold of 0.9 for the comparative fit index (CFI) and Tucker Lewis Index (TLI) values to indicate acceptable fit (Kline, 2015).

We then conducted hierarchical ordinary least squares regression analysis with risk perception as the dependent variable. Hierarchical regression allows the researcher to enter independent variables in a series of steps, with each round of results demonstrating the relative relationship of the variables to the dependent variable while controlling for previously entered variables (Cohen et al., 2002). We used two diagnostic tests to identify potential multicollinearity issues: bivariate correlations and variance inflation factors (VIFs) (Chennamaneni et al., 2015).

For our regression models (Table 3), we entered the six demographic variables (age, gender, race and ethnicity, income, educational attainment, and political ideology) and two environmental variables related to lead exposure (presence of children under the age of three in household, living in a residence built prior to 1978) in the first block. In the second block, we added the trust in government management of lead and subjective knowledge of lead variables. In the third and final block, we incorporated the trust–knowledge interaction term to assess whether and how subjective knowledge moderated the relationship between trust and risk perception.

3.4 | Participants

Qualtrics estimated ∼40,000 individuals were solicited for survey participation. A total of 3939 individuals met the quota requirements, accepted the invitation to participate, and started the survey. A total of 1036 complete and valid survey responses were collected with our specific screening criteria. The sampling frame for opt-in panels is unknown, so we were unable to calculate a response rate (Callegaro & DiSogra, 2008). However, our completion rate, or the proportion of screened and completed surveys to the total number of surveys started, was 26.3% (Eysenbach, 2004). One respondent was removed due to answering "prefer not to say" to the gender item, resulting in a final sample of 1035.

TABLE 3 Summary of hierarchical ordinary least squares regression models for variables predicting perceived risk of lead exposure (n = 1035).

Model Independent variable	Model 1 β	Model 2 β	Model 3 β
Age	−0.23***	−0.14***	−0.12***
Gender (female)	−0.05	0.05	0.05
Race/ethnicity (non-White)			
Black or African American	0.01	0.03	0.03
American Indian or Alaska Native	−0.07*	−0.05	−0.05
Hispanic or Latino	0.00	0.02	0.03
Combined[a]	−0.04	0.01	0.02
Education (at least college)	0.09**	0.03	0.02
Income	0.12***	0.04	0.03
Political ideology (liberal)	0.08**	0.05	0.05
Presence of child ≤3	0.04	0.02	0.02
House built pre-1978	0.08*	0.05	0.05
Trust in government	–	0.19***	0.18***
Subjective knowledge	–	0.35***	0.34***
Trust × subjective knowledge	–	–	0.11***
Adjusted R^2	0.10	0.27	0.28
F for ΔR^2	11.78***	119.13***	16.03***

[a]Includes Asian, Native Hawaiian/Pacific Islander, and Biracial/Multiracial.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

4 | RESULTS

4.1 | Sociodemographic characteristics

Survey respondents were 49.8% male. 37.7% of respondents were White (not including those who identify as Hispanic), 17.7% Black/African American, 16.1% American Indian/Alaska Native, 13.9% Hispanic or Latino, and the remainder belonged to other racial or ethnic groups. A one-way ANOVA of the racial and ethnic groups in relation to perceived risk showed statistically significant differences across groups [$F(5, 639) = 4.81$, $p < 0.001$]. A Tukey's test found that the mean value for perceived risk of lead exposure was significantly different between the following pairs: Black/African American risk perceptions were higher than American Indian/Alaskan Native respondents' perceptions ($p = 0.004$, 95% confidence interval [C.I.] = [0.07, 0.60]), and Hispanic/Latino risk perceptions were higher than those of American Indian/Alaskan Natives ($p = 0.005$, 95% C.I. = [−0.63, −0.07]). The average age of respondents was 46.1 years (SD = 16.9). Note that 54.6% of respondents held a bachelor's degree or higher. We compared demographic information from the sample with national census data for reference (Table 1).

4.2 | Variable and model specification

We assessed our measurement of perceived risk and trust in government through exploratory factor analyses followed by confirmatory factor analyses. In the EFA for risk, the initial 17 items in the scale the Bartlett's test of sphericity resulted in a Pearson's chi-square statistic, $\chi^2(136, n = 1035) = 12{,}328.16$, $p < 0.001$, and a Kaiser-Meyer-Olkin (KMO) test value of 0.93. The Cronbach's alpha for the perceived risk of lead exposure, and each of the four individual constructs, exceeded the reliability threshold, except for perceived exposure (Cronbach's alpha for overall perceived risk of lead exposure = 0.914; affect = 0.928; perceived exposure = 0.575; perceived severity = 0.888; perceived susceptibility = 0.736). One of three exposure items, "In the coming year, how confident are you that you will be exposed to lead where you live?", was removed from further analysis, which increased internal reliability of perceived exposure to 0.772 (Spearman–Brown coefficient). Reverse coded items have been shown to negatively affect scale reliability (Weems & Onwuegbuzie, 2001). This issue held true for one other item in the perceived susceptibility variable, "How protected would you feel if you were exposed to lead?". To improve scale reliability, we removed this item, which increased the construct reliability to $\alpha = 0.878$. These two removed items also possessed low communality values in the EFA (<0.10), further supporting their removal. Results from a confirmatory factor analysis to test the four-factor structure of our perceived risk variable indicated a reasonable fit. The four-factor structure fit the data reasonably well ($\chi^2(86) = 1188.24$, $p = 0.000$, CFI = 0.908, TLI = 0.887) (Figure S1). The results of an EFA for general trust demonstrated suitability for factor analysis ($\chi^2(28, n = 1035) = 5588.96$, $p < 0.001$, KMO value 0.92). Results from a confirmatory factor analysis to test the one-factor structure of our general trust variable indicated a reasonable fit ($\chi^2(20) = 575.79$, p = 0.000, CFI = 0.900, TLI = 0.861) (Figure S2).

Bivariate correlations for all predictor variables were lower than 0.70, indicating that multicollinearity is likely not a major concern for subsequent model testing (Dormann et al., 2013) (Table S1). All VIF values were below the recommended cutoff of 10 (Shieh, 2011) except for trust in government management of lead and subjective knowledge of lead. Interaction effects can introduce multicollinearity into the model but mean centering the main effects variables can reduce this issue (Aiken & West, 1991; Irwin & McClelland, 2001; Shieh, 2011). Once both the trust and subjective knowledge variables were mean centered, all VIF values fell below 10.

4.3 | Regression analyses

Table 3 reports the results of the three-stage hierarchical multiple regression analysis. Model 1 ($R^2 = 0.10$) includes sociodemographic variables, political ideology, and the environmental factors that may affect perceived risk of lead exposure. Older respondents perceived a lower risk from lead exposure ($\beta = -0.23$, $p < 0.001$), as did respondents who identified as American Indian or Alaska Native ($\beta = -0.07$, $p < 0.05$). Higher levels of education ($\beta = 0.09$, $p < 0.01$), higher income ($\beta = 0.12$, $p < 0.001$), and identifying as more politically liberal positively predicted perceived risk of lead exposure ($\beta = 0.08$, $p < 0.01$). Of the environmental factors, only living in a residence built prior to 1978 significantly predicted perceived risk of lead exposure ($\beta = 0.08$, $p < 0.05$). Individuals living in pre-1978 dwellings perceived a greater risk than those who answered "no" or "I don't know."

Model 2 incorporates the two primary study variables, trust in government management of lead and subjective knowledge about lead. Both variables positively and significantly predicted perceived risk of lead exposure (trust: $\beta = 0.19$, $p < 0.001$; knowledge: $\beta = 0.35$, $p < 0.001$). Several variables from the previous model were no longer significant. Only age retained significance such that older respondents perceived less risk from lead exposure ($\beta = -0.14$, $p < 0.001$). The R^2 value for Model 2 is almost triple that of Model 1 and significant, suggesting slightly better model fit with a moderate effect size ($R^2 = 0.27$) (Ferguson, 2009).

The third and final model introduced the interaction term between trust in government management of lead and subjective knowledge of lead to examine the potentially moderating effect of subjective knowledge on perceived risk of lead exposure. There was a significant difference between Models 2 and 3 although the increase in the R^2 was marginal ($R^2 = 0.28$). The effect of age remained the same as in the previous models (age: $\beta = -0.12$, $p < 0.001$). Older respondents perceived less risk of lead exposure. Both main effect variables, trust in government management of lead and subjective knowledge about lead, retained their significance (trust: $\beta = 0.18$, $p < 0.001$; knowledge: $\beta = 0.34$, $p < 0.001$). The interaction effect between trust and subjective knowledge was also significant ($\beta = 0.11$, $p < 0.001$). The effects of gender, race (specifically identifying most closely as Black or African American, Hispanic or Latino, or those grouped into the combined race category), and having children under the age of three were not statistically significant in any of the models. The interaction effect (Figure 1) between trust and subjective knowledge was significant ($\beta = 0.11$, $p < 0.001$). The interaction plot shows that respondents with higher subjective knowledge of lead were more likely to have both higher trust in government and higher risk perception compared to respondents with lower subjective knowledge.

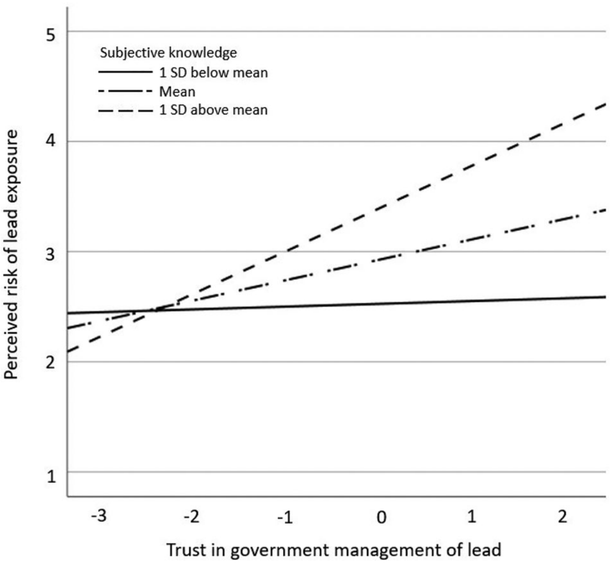

FIGURE 1 Interaction plot showing respondents grouped by three levels of subjective knowledge: less than 1 standard deviation below, within 1 standard deviation, and above 1 standard deviation of the mean, plotted with trust in government management of lead on the *X*-axis and perceived risk of lead exposure on the *Y*-axis.

5 | DISCUSSION

Lead exposure affects half of adults living in the United States today, yet it does not appear to be an issue of high concern for the general population. On average, our respondents' mean risk perceptions were between "a little concerned" and "somewhat concerned" about lead. Successful public management of lead exposure risks—especially effective communication to encourage personal protective behavior—requires national-level attention (Turaga et al., 2014). We found that when subjective knowledge about lead is low, trust in government management of lead and perceived risk of lead exposure are also low. This finding suggests that communication efforts aimed at increasing levels of confidence in lead-related knowledge and trust in managing agencies could increase lead exposure risk perception. U.S. agencies tasked with protecting public health during the COVID-19 pandemic, like the CDC, have begun to reckon with the lack of trust in their agencies (Nan et al., 2022) and, given our respondents rated the government as only "somewhat" trustworthy on average on this issue, the same work needs to be done for public messaging about lead exposure risks.

Theoretically, our study adds nuance to previous research on relationships between perceived risk of a human-caused hazard, trust in government management of that hazard, and subjective knowledge of the hazard. In contrast to some human-caused hazards that have been studied in the past (e.g., nuclear power; Viklund, 2003), the government's role in both primary prevention of lead exposure through direct removal and secondary prevention of exposure through education and monitoring programs is a defining characteristic of how lead must be managed. Lead is a widespread environmental contaminant that is difficult to fully remove, and there is no safe level of lead exposure for children, so secondary prevention to encourage individual protective action is a necessary government function, particularly in relation to families with young children. The 2022 National Lead Poisoning Prevention Week Information Kit incites people to "Get the Facts, Get Your Child Tested, and Get Your Home Tested" and emphasizes the risks of exposure (US EPA, 2022). We believe the government's secondary exposure prevention role helps explain our finding that both higher trust in government management and higher subjective knowledge of the lead risk were significantly related to higher risk perception (H1, H2). Why we found a different relationship between trust in government and risk perception than many past studies is likely due to differences in types of hazard, type of trust, and what the government entities and their actions look like. One partial explanation may be related to the particularities of the government entities and their functions. For instance, Jeong and Yim (2023) found a positive correlation between risk perception about COVID-19 and trust in government, and furthermore, that risk perception had a positive effect on information seeking about the infectious disease when someone had high trust in government. The distinction made between partial and impartial government institutions by Kulin and Johansson Sevä (2020) may be important here, as the government entities messaging about lead exposure would be classified as impartial in this formulation, and people expect that this side of government be characterized by quality and fairness, which are components of trust (Rothstein, 2009). While we did not measure information seeking in this study, this behavior is often positively correlated with subjective knowledge (e.g., Avery & Park 2021). The relationship between subjective knowledge and risk perception may also be explained by the general population's relatively low exposure to media and government messages about lead, compared to studies focused only on people living in a contaminated area (e.g., Grasmück & Scholz (2005)). While people in a known contaminated area may develop heuristics over time to cope with living in a risky place, thereby reducing risk perceptions, the U.S. general population has likely not developed these heuristics.

Our analysis revealed an interaction effect for subjective knowledge about lead. Respondents who believed themselves to be knowledgeable about lead reported higher levels of trust in government management of lead and high levels of perceived risk of lead exposure (H3). We believe this effect is also related to the importance of secondary prevention for lead risk management, such that when someone trusts the government as a source of information about lead risk, their subjective knowledge increases, as does their perception of the risk. Another possible explanation for this finding is that individuals who feel uninformed on the issue of lead exposure are reluctant or unable to form strong opinions on the risk of lead exposure or the government's efforts to manage lead risks. Those respondents who perceived their understanding of lead risks to be limited may therefore have chosen to disengage with the issue entirely.

Age significantly and negatively predicted risk perception in all models, consistent with previous findings that older individuals frequently report lower environmental concern (Casey & Scott, 2006; Haltinner & Sarathchandra, 2021). Regarding other demographic and ideological variables, we found (significant in Model 1) that respondents who reported higher household incomes perceived higher risk of lead exposure relative to those respondents with lower household incomes, despite low-income households being at an increased risk of negative health outcomes as a result of lead exposure and other environmental health hazards (Brown, 1995; Marshall et al., 2020). This finding could be explained, as Shen and Saijo (2008) argue, by the reasoning that wealthier people have more capacity to worry about issues like lead exposure because their basic and immediate needs have been met. Education level was positively and significantly associated with higher risk perception in Model 1 but was no longer significant when the subjective knowledge variable was added in Models 2 and 3. More research is needed to understand the different roles objective knowledge acquired through education and subjective knowledge plays in the perception of lead risks. Identifying as more politically liberal significantly predicted perceived risk in Model 1. Previous research asserts conservative leaning individuals tend to be less sensitive to "diffuse threats," or those threats that collectively affect individuals and others like lead exposure (Choma et al., 2013). Because political ideology is related to variables, we cannot accurately account for with our panel data, particularly urban versus rural residence, and this relationship should be tested more thoroughly in future research.

Though racial and ethnic minorities in the United States are known to be disproportionately exposed to environmental contaminants (Ash & Boyce, 2018; Mennis, 2002; Whitehead & Buchanan, 2019), we found only one category—American Indian/Alaska Native—to be significantly different from White respondents and negatively associated with risk perception in Model 1. American Indian populations have higher blood lead levels than the general U.S. population, attributable to where they live, cultural practices (e.g., harvesting traditional foods from contaminated soils), and individual behaviors (e.g., smoking) (Li et al., 2022). It is possible that similar to the communities in Grasmück and Scholz's (2005) study, these respondents cope with disproportionate exposures through heuristics that reduce their risk perceptions.

Respondents in households with children under three did not perceive statistically significant greater risk from lead exposure, even though young children are especially susceptible to acute and chronic health effects (Bellinger et al., 2017). This result is consistent with research conducted by Harclerode et al. (2016). In contrast, individuals living in residences built prior to 1978 consistently perceived higher risk of lead exposure. Respondents appear to be aware of the potential presence of lead paint in older homes. This finding could suggest that household exposure, particularly to lead-based paint, might be a useful entry point for future efforts to increase awareness and perceived risk of lead exposure.

Our study has a number of limitations that present opportunities for further research. In terms of our sample and analysis, we maximized sample representativeness with the use of quotas, but because of the nature of this online survey, the findings here are not fully representative of the national population. Second, we acknowledge the potential influence of the COVID-19 pandemic on our respondents' level of engagement and ability to critically consider the risk of lead exposure. Previous research has demonstrated that perceived risk of environmental issues may vary in response to other pressing societal issues, often referred to as the "finite pool of worry" (Bostrom et al., 2020; Evensen et al., 2021). Individuals possess limited emotional resources such that as concern increases for one issue (e.g., COVID-19), concern for other issues decreases. Third, our regression models did not demonstrate exceptional fit. However, this measure does not necessarily indicate that the models are not psychologically plausible in the context of lead exposure (Siegrist, 2021). Fourth, we acknowledge that the use of correlational data limits our ability to determine causal relationships between this study's primary variables. Lastly, a more comprehensive measure to contextualize respondents' objective level of risk, beyond the two variables (children under three, pre-1978 housing) included in the present study, could further elucidate variations in perceived risk, as well as providing additional opportunities to tailor risk messages.

Our study has theoretical limitations related to the primary independent variables of trust and subjective knowledge that would benefit from further investigation. We did not ask separate questions about trust in government management of lead for primary prevention versus secondary prevention activities in our questionnaire due to length constraints. Because we suspect the differences between these types of activities contributed to the direction of relationship between trust and risk perception, future research on this type of hazard should parse the differences between these two types of activities. We also see a need for research differentiating between trust in specific government agencies involved in the risk management of lead, including EPA, CDC, and local public health districts (e.g., Hamm et al., 2019). There are also other measures of trust that could be tested. For example, Stern and Coleman (2015) offer an alternative typology of trust that includes dispositional trust. Dispositional trust can refer to a general predisposition to trust others, regardless of context. Alternatively, it can describe an individual's tendency to trust a person or institution because of perceived judgements of authority and legitimacy. This type of trust may be particularly important in large-scale management contexts because individuals may struggle to evaluate the number of individuals and institutions involved (Sønderskov, 2011). With respect to our knowledge variable, we only measured subjective knowledge because objective knowledge has been less consistently predictive of attitudes and behaviors than subjective knowledge in past studies

(Ellen, 1994) and also because we were concerned about respondents reacting badly to being "quizzed" and dropping out of our survey. However, research shows subjective and objective knowledge are often misaligned (Carlson et al., 2009), so future studies should test these differences for knowledge of lead hazards. Lastly, future communication research could test the efficacy of different message frames to increase risk perception, trust, and protective behavior to generate actionable recommendations to public health agencies.

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SUPPORTING INFORMATION

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

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