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HIGHLIGHTS

- We explored American risk perceptions of nuclear energy pre- and post-Fukushima.
- Impacts of the disaster endured, likely due to relatively high media coverage.
- Conservatives who paid more attention to media perceived less risk post-Fukushima.
- Media coverage can serve to polarize opinions instead of mainstreaming them.

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ABSTRACT

Aim: This study examines risk perceptions toward nuclear power before and after the Fukushima Daiichi disaster using nationally representative survey samples of American adults.
Scope: On March 11, 2011, a magnitude 8.4 earthquake, the largest in the nation's history, occurred off the coast of Japan. The earthquake produced a devastating tsunami that flooded areas of the Fukushima Daiichi nuclear plant and resulted in a loss of power to the plant's cooling system. In the weeks that followed, the world watched as Japanese and international nuclear power safety experts scrambled to contain the damage and prevent a full meltdown. Although the Fukushima Daiichi disaster was heavily covered in media, there is little empirical research on how this coverage impacted audience risk perceptions. Our analysis goes beyond examining aggregate risk perceptions, instead focusing on how specific sub-populations responded to the disaster.
Conclusion: We found that ideological groups responded differently to the events in Japan. In particular, risk perceptions among conservatives decreased following the incident. Moreover, we found that media use exacerbated these effects. We discuss possible explanations for these findings.

1. Introduction

Despite the decline of nuclear power in the overall energy mix in the United States, there had been a slow but steady increase in public support for new power plants during the first decade of the 21st century, a sign of the "nuclear renaissance" as the American public reassessed the technology as a potentially "cleaner" alternative to coal-fired power plants (Jones, 2009). A total of 23 applications for 37 new power plants were expected to be filed between 2009 and 2015, an indication that the industry was optimistic about its future and had begun to leave behind the legacy of distrust and disaster that was the hallmark of nuclear energy in the late 1970s through the 1980s (United States Nuclear Regulatory Commission, 2011). For an inclusive study on the future of nuclear power in the United States, see Ansolabehere (2010).

Although decades have passed since the accidents at Chernobyl and Three Mile Island, these events have not been erased from the public's collective memory. Events with such severe and unexpected consequences tend to carry significant weight in risk perception, and it was postulated that a major accident accompanied by the ensuing media coverage would likely reverse growing support for nuclear energy and mark the end of the "nuclear renaissance" (Sjöberg, 2003).

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On March 11, 2011, a magnitude 9.0 earthquake, the largest in the nation's history, occurred off the coast of Japan resulting in a devastating tsunami. The Fukushima Daiichi nuclear plant was located in the tsunami zone and separated from the ocean by a seawall. Following the earthquake, the nuclear reactor at the plant shut off automatically, as it was designed to do (American Nuclear Society Special Committee on Fukushima, 2012). An hour after the earthquake occurred, the diesel generators that served as back-up power for the power plant's cooling system shut down as a result of flooding from the tsunami, leading to the disaster. The facility began overheating, and in the weeks following, the world watched as Japanese and international nuclear power safety experts scrambled to contain the damage and prevent a full meltdown (Sanger and Wald, 2011).

Predictably, in the wake of the disaster, U.S. public support for nuclear energy declined from 47 percent to 39 percent, while opposition increased from 42 percent to 52 percent (Pew Research Center, 2011a). Notably, these declines occurred at a time when public opinion toward other energy sources remained relatively unchanged (Pew Research Center, 2011a). Even in polls conducted several months later, opposition to nuclear power remained high among Americans (Pew Research Center, 2011b). Yet, despite the overall decline in support following Fukushima, about a quarter of Americans (24 percent) still think that nuclear power plants in the U.S. are safer than those in Japan, compared to 53 percent who say the two countries are on par in terms of safety (Pew Research Center, 2011a). While the event was heavily covered in American media in the weeks and months after its occurrence, initial public opinion reports failed to examine how survey participants used media to learn about the accident. Initial reports showed correlations between education, gender, support and/or risk perceptions, but these studies did not account for the impact of media use on perceptions of nuclear energy.

In this study, we explore how American attitudes toward nuclear power changed following the events at the Fukushima Daiichi power plant. Specifically, we examine the predictors of nuclear energy risk perceptions, looking for changes in these relationships in the wake of the biggest nuclear disaster since Chernobyl. Building on literatures in political science and communication, we examine risk perceptions across different levels of political ideology and media use. By comparing changes in nationally representative datasets over time, we explore the dynamics behind risk perceptions for groups that differ based on media attention patterns and ideology. These data provide a unique opportunity to track perceptions of risk in the aftermath of a nuclear disaster. Moreover, they provide an opportunity to explore the role of both values and media attention in exacerbating or attenuating such perceptions.

2. Literature review

2.1. Risk perception and nuclear energy

Although nuclear disasters are low-probability events, the consequences can be extreme. Like perceptions relative to chemicals and environmental contaminants, nuclear power is associated with cancer, a dread-known risk (Lemyre et al., 2006). This is consistent with research finding that the communication of radiation risk following a nuclear accident contributes to the perception of it as a major public health issue (Smith, 2007). Individuals will perceive greater risk if the exposure to contaminants occur over long periods of time and they perceive a lack of personal control over the health effects of exposure (Vaughan, 1993). The uniqueness of nuclear power further complicates the issue since risks to the public can occur at several stages of the supply chain. The public perceives risk in the mining of nuclear materials, material transportation, production of power, and storage and disposal of waste (e.g. Slovic, 1987; Slovic et al., 1991; van der Pligt, 1992). For a comprehensive overview of public attitudes towards nuclear waste, see Jenkins-Smith (2011).

Perception of risk has a direct, negative effect on attitude toward nuclear energy, and is the strongest predictor of willingness to take action against nuclear power (Whitfield et al., 2009). More specifically, support and risk perceptions are negatively correlated (Slovicet al., 1982)[2]. Research has shown that opposition to building more nuclear power plants in the U.S. increased from 20 percent to more than 60 percent in the 1980s (Rosa and Freudenburg, 1993). European data show a similar historical pattern, but amplified further by the impacts of the Chernobyl accident in 1986 (van der Pligt, 1992). During this period, nuclear energy and radioactive waste were seen as uniquely 'dreaded' and unknown risks (Pidgeon et al., 1992; Slovic, 1987), due in part to their 'invisible' and long-lasting effects, waste disposal concerns, and a historic association with atomic weaponry (e.g. Slovic et al., 1991). In addition to high public risk perception, there is also intense public distrust of government agencies and nuclear industries to provide truthful information and manage the risks of nuclear power responsibly (Parkhill et al., 2010; Poortinga and Pidgeon, 2003; Rosa and Clark, 1999; Wynne, 1992). The patterns noted above placed the nuclear energy industry in a precarious position in the aftermath of Fukushima —one where information flow to the public could seriously amplify risk perceptions and decrease support.

In the present study, we combine data collected pre- and post-Fukushima to explore American perceptions of risk related to nuclear power in the wake of the largest nuclear disaster since Chernobyl. Although these are not panel data, our samples are representative of the U.S. population and we treat the Fukushima accident as a quasi-experimental stimulus. Our data collection periods were fortuitously timed around the accident, allowing us to take advantage of the incident in our analysis. Our study builds on the findings of Binder et al. (2011) by exploring the extent to which partisan groups may have responded differently to the events in Japan, as well as media coverage of those events. We begin with a discussion of media impacts on public risk perceptions before discussing how media influences may differ across a variety of population sub-groups.

2.2. Nuclear energy in the media

The news media operate as a primary channel through which the public learn about science, technology and risk (National Science Board, 2012). The notion that news media are a prominent source of information about risk is consistent with findings in studies of the social amplification of risk—a framework proposed for understanding how and why certain risks capture the public's attention. This body of literature has documented the effect of media on risk perceptions with respect to issues ranging from 'mad cow disease' (Fife-Schaw and Rowe, 2000; Reilly, 1998) to genetically modified foods (Frewer et al., 2002).

The effects of media have also been examined using issues with a nuclear component. For example, one study of the interaction between nuclear risk perceptions and media coverage focused on the Federal Bureau of Investigation (FBI) raid of the Rocky Flats plant, a former U.S. nuclear weapons production facility, outside Denver, Colorado in 1989 (Flynn et al., 1998). While not a

[2] For the purpose of this study, we are interested in risk perceptions and the factors that inform individual risk perception in the aftermath of a severe risk event, which in turn can be expected to inform public support.

nuclear accident like Fukushima, the intense news interest in the misconduct of plant operators, and serious concern about the potential for a dread risk event, played a key role in stigmatizing the Rocky Flats community. While all respondents in the study had similar impressions, those who recalled media coverage of the raid exhibited stronger negative responses toward the community and valued houses within the community at lower rates than comparable homes in nearby communities (Flynn et al., 1998). Kasperson (2012) suggests that hazard events with a nuclear component are especially vulnerable to amplification effects due to the "dreaded," unseen, and poorly understood nature of radiation. Therefore, we expect media use to play a moderating role in risk perceptions, specifically affecting perceptions of nuclear power negatively:

H1: Media use will moderate the effects of the incident on public risk perceptions. In other words, greater media use will increase risk perceptions of nuclear energy following the Fukushima Daiichi nuclear accident.

Given our understanding of the role of media in formation of risk perceptions, the results of opinion polls in the aftermath of Fukushima are somewhat surprising. While polls demonstrated decreases in those favoring nuclear energy post-Fukushima (Pew Research Center, 2011b), the decline was not necessarily as severe as one would expect. Despite the widespread news coverage, the magnitude of the crisis and the comparisons between Fukushima Daiichi and Chernobyl, post-disaster public support for nuclear energy remained higher than it was during the 1970s and 1980s. However, recent scholarship has started to examine opinion formation and risk through a more nuanced lens, and may begin to explain the overall relatively small declines in support for nuclear power noted above.

2.3. Perceptual filters and partisanship

Value predispositions and ideology are often used as heuristics (Chaiken et al., 1989) in decision-making (Brossard et al., 2009; Scheufele, 2006). Individuals are "cognitive misers" who use heuristics to make decisions and form opinions (Popkin, 1991). For example, political conservatives are typically less supportive when it comes to nanotechnology (Lee et al., 2005), stem cell research (Nisbet, 2005), and agricultural biotechnology (Brossard and Nisbet, 2007). In general, however, conservatives are more in favor of nuclear energy than their liberal counterparts. Polls indicate that this trend persisted post-Fukushima as, despite an overall drop in the percentage of those supportive of nuclear power, partisan differences in opinions persisted. The greatest loss of support occurred among Republicans (57 percent to 49 percent), followed by Independents[3] (47 percent to 41 percent), while support from Democrats declined from 36 percent to 31 percent (Pew Research Center, 2011a). Given the margin of error, only the decrease in support among Republicans was significant (Pew Research Center, 2011a). The non-significant drop in support among Democrats may be due to a "floor effect"; it is likely that support among members of this group was low enough prior to the event that it was only marginally affected by the disaster. Despite an overall decline, support among Republicans remained higher than Democrats or Independents[4]. Given the existing evidence, we hypothesize that:

H2: Individual risk perceptions of nuclear energy will be differentially affected by the Fukushima Daiichi nuclear accident, depending on political ideology. In other words, ideology will moderate the impact of the disaster on individual risk perceptions.

Thus far, we have outlined the role that media may play as an amplification station for risk events, as well as the possibility that certain partisan groups may respond differently to a hazard event. In this section we expand upon our discussion of media as a potential amplification station by outlining the manner by which media influences on risk perceptions might be contingent on factors such as a respondent's political partisanship. There is little empirical work in this area, however, scholars have examined factors such as interpersonal discussion (Binder et al., 2011) and found that discussion frequency can serve to both amplify and attenuate risk perceptions toward a bio- and agro-defense facility. More importantly for our purposes, however, they found that these effects were contingent on a respondent's initial attitude. Those who were opposed to the facility perceived greater risks as their discussion frequency increased, and those who were supportive of the facility perceived fewer risks the more they discussed the issue. That is, prior attitudes served to moderate the effects of discussion on risk perception.

In much the same way that discussion both amplified and attenuated risk perceptions toward a bio- and agro-defense facility depending on the prior attitudes of the discussion participants, we anticipate that partisan groups will evaluate media content differently in the wake of the Fukushima meltdown. For example, partisans may put greater emphasis on information that confirms their initial viewpoints – a process known as congruency or confirmation bias – or, they may spend greater time counter-arguing information that runs in contrast to their original position – a tendency known as disconfirmation bias (Taber et al., 2009). These tendencies have been demonstrated for charged political issues, such as affirmative action and gun control (Taber and Lodge, 2006) and even less publicized and polarized scientific issues such as biofuels (Cacciatore et al., 2012). With this in mind, we hypothesize that:

H3: Media use habits will moderate the effects of ideology on individual risk perceptions pre- and post-Fukushima. Therefore, we will have significant three-way interactions between media use, ideology, and year.

Thus far, there have been only three studies of the impacts of the Fukushima accident, primarily because having data on public attitudes towards nuclear energy pre- and post-Fukushima is reliant on serendipity. Of the three studies, two were conducted in Switzerland with 790 and 463 participants, respectively (Siegrist and Visschers, 2012; Visschers and Siegrist, 2012), while the other used a sample of 32 participants in Italy (Prati and Zani, 2012). Participants in the Swiss studies were randomly selected from the telephone directory in the German-speaking region of Switzerland and the final sample was more male and educated than the general Swiss population. These data were collected within two months after the disaster, and unsurprisingly, found increases in risk perceptions and decreases in public support for nuclear energy (Prati and Zani, 2012; Siegrist and Visschers, 2012; Visschers and Siegrist, 2012). However, the negative impact on public support in Switzerland was only moderate and supports the assumption that people's understanding of technological accidents

[3] In the United States, Independents are voters who do not align themselves or identify with either the Democratic or Republican Party.

[4] Although many public opinion polls observe trends related to partisan identification, partisanship is a less ideal predictor of voting patterns than ideology (Abramowitz and Saunders, 2006; Inglehart and Klingemann, 1976). Scholars have shown that the correlation between party identification and ideology has strengthened over the years and is due to the influence of ideology on partisanship

(*footnote continued*)
(Abramowitz and Saunders, 2006). Therefore, in our examination of predictors of public risk perceptions of nuclear power, we use ideology instead of partisan identification in our models.

are based on their prior attitudes and beliefs (Siegrist et al., 2008; Siegrist and Visschers, 2012). The current study is the first to explore the effects of the accident on risk perceptions with a large sample representative of the population of the United States. Moreover, it is also the first to empirically test for differential effects based on political ideology and media attention in the wake of the Fukushima disaster.

3. Method

3.1. Data and participants

Data for this study were obtained as part of two broader online surveys using a probability-based web panel run by GfK Knowledge Networks that is representative of the United States. The first survey was conducted in July 2010, and the final sample size was 2338 with a completion rate of 54.2 percent. The second survey was conducted between December 2011 and January 2012. The final sample size was 2806 with a completion rate of 49 percent. Since we were interested in interaction effects based on year, we combined the 2010 and 2011 datasets and ran our analyses on this newly created "merged" data file[5]. Post-stratification weights were applied to each dataset prior to analyses and merging in order to ensure the comparability of the data.

Both data collections contained experimental manipulations that we controlled for prior to our analyses and merging[6]. We controlled for exposure to the experimental manipulations by residualizing the variables of interest using regression models with a series of dummy variables as independent variables in the individual datasets. When running analyses on the merged data file, variables measured after exposure to the experimental stimulus (e.g., risk perceptions, scientific deference, knowledge, and benefit perceptions) were residualized through ordinary least squares (OLS) regression in order to control for the effects of the manipulation.

3.2. Measures

3.2.1. Dependent variables

Risk perceptions served as the dependent variable of interest in this analysis. As the data were collected at different times as part of broader individual experiments, the scales used to measure risk perception were different. In the pre-Fukushima data, risk perception was measured using a 10-point scale (1="Do not agree at all," 10="Agree very much") asking respondents how much they agree with the following four statements related to nuclear power: (i) "Nuclear power may lead to more pollution and environmental contamination," (ii) "Nuclear power may lead to contamination of water supplies," (iii) "Nuclear power may lead to new human health problems," and (iv) "Nuclear power may increase the risk of a nuclear accident in the United States." The four items were averaged to create an index with scores ranging from 1 to 10 ($M=6.09$, SD=2.30, *Cronbach's alpha*=.92). In the post-Fukushima data, risk perception was measured by asking respondents how risky they thought nuclear power was for society. This item was based on a 7-point scale, where 1= "not all risky" to 7="very risky" ($M=4.67$, SD=1.64). To make these comparable across years, we trichotomized the dependent variable in both the pre- and post-Fukushima datasets. In both datasets, respondents were categorized into 'Low', 'Medium' and 'High' risk perception.

In the pre-Fukushima dataset, we recoded our continuous measure of risk perceptions such that those scoring 1 through 4.99 were classified as having 'Low' risk perceptions, those scoring 5.00 through 6.00 (the midpoint of the scale) were classified as having 'Medium' risk perceptions and those scoring 6.01 through 10 were classified as having 'High' risk perceptions ($M=1.21$, $SD=0.83$). For the post-Fukushima dataset, we recoded our single-item measure such that those scoring 1 through 3 were classified as having 'Low' risk perceptions, those scoring 4 (the midpoint of the scale) were classified as having 'Medium' risk perceptions and those scoring 5 through 7 were classified as having 'High' risk perceptions ($M=1.31$, $SD=0.83$). As noted, we then residualized our measures to control for any impact of our experimental manipulations and merged the measures. The residualizing process changed the nature of our trichotomized risk perception variable, leaving respondents with a unique value on that measure that fell somewhere between −2.97 and 2.86 ($M=-0.01$, $SD=0.92$), where higher positive values indicate greater perceptions of risk[7].

3.2.2. Independent variables

As analyses on our merged data file utilized data from two separate data collections, we controlled for the year of data collection with a dummy variable. *Year* was measured as a dichotomous variable, with those taking the survey pre-Fukushima coded as '0' and those taking the survey post-Fukushima coded as '1'. Age, gender, education and income were included in our model to control for demographic influences on dependent variable. *Age* was measured as a continuous variable (pre-Fukushima: $M=46.45$, $SD=17.0$; post-Fukushima: $M=49.32$, $SD=15.88$). Gender was measured with a simple dichotomous measure and the proportion of female-to-male respondents was similar across the two data collections (pre-Fukushima: 51.7 percent female; post-Fukushima: 49.6 percent female). *Education* (median: "some college, no degree") and *household income* (*Median*: $40,000 to $49,999) were measured categorically in both datasets.

Ideology was assessed by asking respondents about their ideology on social and economic issues. In the pre-Fukushima dataset, the two items were measured on a scale ranging from 1 to 6, with 1 being "Very liberal" and 6 being "Very conservative". The items were combined to create an averaged index ($M=3.62$, SD=1.24, Pearson's $r=.75$). The post-Fukushima dataset asked the same questions using a scale that ranged from 1 to 7, with 1 being "Very liberal" and 7 being "Very conservative". Again, the items were averaged together to create an index ($M=4.22$, SD=1.44, Pearson's $r=.77$). Due to the slightly different scales, we standardized these items prior to merging our data.

As previous research has demonstrated the importance of *deference to scientific authority* in predicting public response to

[5] GfK Knowledge Networks uses probability sampling and provides weights to make their sample representative of the population. In both cases, weights were applied to these data. Of course, given the nature of probability sampling, we do not expect our samples to be identical. However, we are confident that these data are comparable. In addition, we include a dummy variable (*year*), which effectively controls for the nature of our samples as it differentiates data collected pre- and post-Fukushima.

[6] The study conducted in 2010 used the issues of nuclear energy and nanotechnology to examine communication elements such as reason, emotion, civility, and heterogeneity of opinions in online media. Respondents were randomly assigned to one of eight blog posts in which the comments had been manipulated. In the 2011 study, respondents were randomly assigned to a news article about one of three issues (nanotechnology, nuclear power, and synthetic biology). Again, an experimental manipulation was employed such that respondents were randomly assigned to one of four possible news articles that each employed a different frame for the issue.

[7] While we ultimately opted to trichotomize our two risk measures, we also considered standardizing the variables in order to make them comparable. However, standardization would result in mean centered variables unique to each of the two samples. While keeping the variables continuous, this process would fail to capture absolute shifts in perceptions of risk following the disaster event, which is a key goal of this analysis.

science and risk issues (e.g. Brossard and Nisbet, 2007; Ho et al., 2008, 2010; Lee and Scheufele, 2006), we included this measure as a control variable in our analysis. Two items were used to measure respondents' deference to scientific authority on a ten-point scale (1="Do not agree at all," 10="Agree very much"): (i) "Scientists should do what they think is best, even if they have to persuade people that it is right," and (ii) "Scientists know best what is good for the public." The items were averaged to create indices for both sets of data (pre-Fukushima: $M=4.43$, $SD=1.98$, Pearson's $r=.50$; post-Fukushima: $M=4.04$, $SD=2.10$, Pearson's $r=.64$).

Attention to newspapers was measured on a 5-point scale (1="None," 5="A lot") by asking the respondents how much attention they pay to news stories about (i) international affairs, (ii) national government and politics, and (iii) science and technology. These three items were averaged to create composite indices for both pre- ($M=2.72$, $SD=1.02$, *Cronbach's alpha*=.88) and post-Fukushima surveys ($M=2.69$, $SD=1.05$, *Cronbach's alpha*=.90). *Attention to news on television* was measured by asking the respondents how much attention they pay to news stories on television, including online TV, about (i) international affairs, (ii) national government and politics, and (iii) science and technology. Items were then averaged to create indices for pre- ($M=2.84$, $SD=1.02$, *Cronbach's alpha*=.89) and post-Fukushima data ($M=2.95$, $SD=1.02$, *Cronbach's alpha*=.89). *Attention to online news* was measured by asking the respondents how much attention they pay to news stories when they go online for news and information about (i) international affairs, (ii) national government and politics and (iii) stories about science and technology. Respondents were asked to exclude online versions of print newspapers or television shows and answer this question based on their usages of blogs, websites, and online-only newspapers. Again, mean indices were created for pre- ($M=2.18$, $SD=1.11$, *Cronbach's alpha*=.93) and post-Fukushima data ($M=2.30$, $SD=1.09$, *Cronbach's alpha*=.92).

As an additional control, we included a measure of nuclear energy knowledge in our regression models. *Knowledge of nuclear energy* was measured using the same three items common to both datasets: (i) "Less than 10 percent of the U.S.'s electricity comes from nuclear power plants," (ii) "There are over 90 operating nuclear reactors in the U.S." and (c) "Nuclear power plants emit significant amounts of carbon dioxide." These items were measured on 5-point scales ranging from "Definitely true" (1) to "Definitely false" (4) with a "Don't know" (5) category. Responses were re-coded so that correct responses were coded as "1" and incorrect or "Don't know" responses were coded as "0". The number of correct responses was tallied for both the pre- ($M=1.06$, $SD=.92$) and post-Fukushima samples ($M=1.25$, $SD=.93$).

As a final control variable, we included a measure of *benefit perceptions of nuclear energy* in our analysis. In the pre-Fukushima dataset we measured this construct using an averaged index of four items on a 10-point scale (1="Not at all," 10="Very much") that asked respondents their level of agreement with the following statements: (i) "Nuclear power will lead to cleaner ways to produce energy," (ii) "Nuclear power may help solve our energy problems," (iii) "Nuclear power may reduce energy dependence on other countries for energy," and (iv) "Nuclear power will lead to reduction of greenhouse gases" ($M=6.34$, $SD=2.19$, *Cronbach's alpha*=.90). In the post-Fukushima data, benefit perceptions were measured by asking respondents how beneficial they thought nuclear power was for society. This item was based on a 7-point scale, where 1= "not all risky" to 7="very risky" ($M=4.51$, $SD=1.71$). To account for the difference in scales across the benefit perception measures pre- and post-Fukushima, we trichotomized benefit perceptions using the same procedure used for risk perceptions. Again, in the pre-Fukushima dataset, we recoded our continuous measure of benefit perceptions into 'Low' (1.00 through 4.99), 'Medium' (5.00 through 6.00), and 'High' (6.01 through 10) categories ($M=1.34$, $SD=0.78$). For the post-Fukushima dataset, we recoded our single-item measure into 'Low' (1 through 3), 'Medium' (4, the midpoint of the scale), and 'High' (5 through 7) categories ($M=1.26$, $SD=0.85$). We then residualized and merged our measures. Again, the residualizing process changed the nature of our trichotomized variable, leaving respondents with a unique value on that measure that fell somewhere between −2.80 and 2.58 ($M=0.04$, $SD=1.04$), with higher values indicative of greater benefit perception.

3.3. Data analysis

We analyzed the data using hierarchical OLS regression models, which test the relationship between the independent and outcome variables by fitting a linear model to the data. Independent variables were entered in blocks in assumed causal order to determine their relative explanatory power. Our regression model was run on a dataset which included both pre- and post-Fukushima data. As a result, we included a block with our dichotomously coded *Year* variable. The merged model included two- and three-way interactions, which allow us to investigate the interactive effects of ideology, media use, and the event itself on public opinion of nuclear energy. The interactions were created by multiplying standardized versions of our variables to prevent multicollinearity between interaction terms and its component parts (Cohen and Cohen, 1983). Two-way interactions were included in the regression models in a separate block after benefit perceptions. Three-way interactions were included in a block after the two-way interactions. In the model, the blocks were ordered as follows:

(1) Year (pre- and post-Fukushima)
(2) Demographics (age, gender, education, household income)
(3) Predispositions (political ideology, deference to scientific authority)
(4) Attention to media (television, newspapers, online media)
(5) Knowledge (control variable)
(6) Benefit perceptions (control variable)
(7) Two-way interactions
(8) Three-way interactions.

4. Results

While risk perceptions both pre- and post-Fukushima are important and of interest, the primary purpose of this study is to explore how risk perceptions shifted in the aftermath of Fukushima across different segments of the population. In particular, we built our hypotheses around the concept of perceptual filters and

Table 1
Variance explained by OLS regression model predicting risk perceptions of nuclear energy ($N=5000$).

	R^2
Block 1: year	0.2**
Block 1: demographics	0.9**
Block 2: predispositions	0.1
Block 3: attention to media	0.6**
Block 4: knowledge	0.1
Block 5: benefit perceptions	0.1**
Block 6: two-way interactions	8.9**
Block 7: three-way interactions	0.4**
Total R^2 (%)	11.4

** $p \leq .001$.

how these may differentially operate in ideological groups due to the inherently political nature of nuclear power. Therefore, of greatest importance to the present study are the interaction results from our regression analysis on the merged dataset. As we are interested in changes in attitudes following the events in Japan, the main effects in the regression model are not conceptually meaningful. Instead, they act as controls for the interaction effects reported below. The variances accounted for by individual blocks in the regression model of the merged dataset are shown in Table 1.

In order to test three-way interactions, it is necessary to include several two-way interactions in our model as controls (Cohen et al., 2003). However, these two-way interactions are also of interest as they represent the main effects of the accident on nuclear energy risk perceptions. In other words, the significant two-way interaction between *ideology* and *year* implies that political ideology affected changes in risk perceptions following the disaster.

In response to H2, Fig. 1 reveals that the events in Japan produced substantially different impacts on risk perceptions depending on individual political leanings. Among moderates, the increase in risk perception is slight. However, among liberals and conservatives, risk perceptions pre- and post-Fukushima are significantly different. There is a dramatic increase in risk perception among liberals following the disaster, while risk perceptions of conservatives declines drastically. It is somewhat surprising that risk perceptions among conservatives are so high before the disaster, since conservatives have historically been more in favor of the technology. However, it is worth noting that the Obama administration was largely supportive of nuclear energy prior to March 2011 (e.g. Wald, 2010). As a result, support among conservatives was likely to be relatively low (and therefore, risk perceptions relatively high), if only to challenge the position of the current administration. Similarly, liberals may have been more supportive of a stance championed by Obama.

In addition to political ideology, attention to each of television, newspapers, and online media also moderated risk perceptions pre- and post-Fukushima. In the interest of brevity we will only illustrate one of these interactions, although the pattern is consistent across each. For example, we observed an increase in risk perception post-Fukushima among individuals who reported paying little attention to TV (Fig. 2). Conversely, among those who paid high attention to media, risk perceptions following the accident declined. These findings run counter to our expectation (H1) that media would amplify risk perceptions following the disaster.

In addition to two-way interactions, our analysis tested a total of three three-way interactions between *year*, *political ideology*, and each of our media attention variables (*attention to newspapers*, *television*, and *online media*). In response to H3, the final block of Table 2 shows that each of the three-way interactions emerged as significant.

Again, in the interest of brevity, we have only illustrated one of these significant interactions: the interaction between *year*, *political ideology*, and *attention to online media* on public risk perceptions. Fig. 3 shows the interaction between *year*, *ideology*, and *attention to online media*. Among both liberals and moderates, risk perceptions were not significantly different following the accident, regardless of how much attention individuals reported paying to online media. Interestingly, while risk perceptions of conservatives who paid relatively little attention to online media declined, a more dramatic decrease was observed among conservatives who paid relatively more attention to online media.

This trend in risk perceptions represents a classic example of perceptual filters at work between ideological groups in the aftermath of the Fukushima Daiichi nuclear disaster, and suggests that liberals, moderates, and conservatives not only processed the

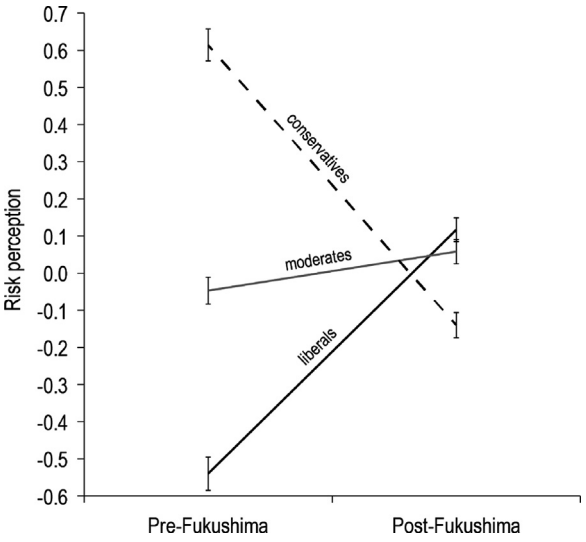

Fig. 1. Public risk perceptions among different ideological groups ($N=5000$) before and after the Fukushima accident. Note: *Y*-axis is only partially displayed; error bars indicate standard error.

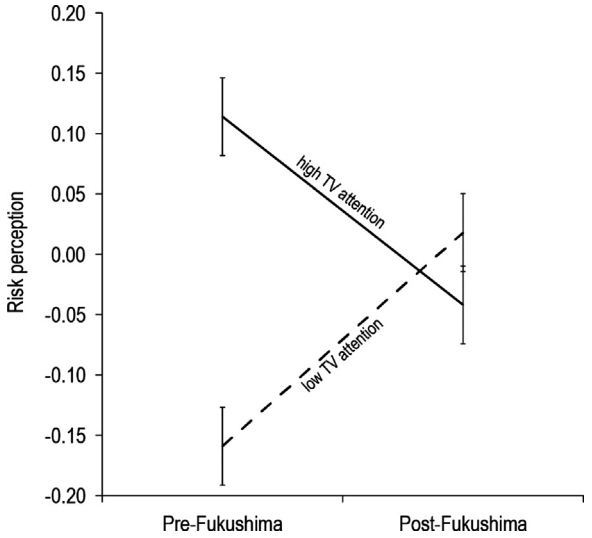

Fig. 2. Moderating effect of media use (attention to television) on risk perceptions prior to and following the nuclear accident at the Fukushima Daiichi power plant ($N=5000$). Note: *Y*-axis is only partially displayed; error bars indicate standard error.

Table 2
Two- and three-way interactions ($N=5000$).

	Before-entry β
Two-way interactions	
Year × ideology	−.41**
Year × attention to TV	−.13**
Year × attention to newspapers	−.11**
Year × attention to Internet	−.09**
Ideology × attention to TV	−.03
Ideology × attention to newspapers	.00
Ideology × attention to Internet	.00
Three-way interactions	
Year × ideology × attention to TV	−.05**
Year × ideology × attention to newspapers	−.05**
Year × ideology × attention to internet	−.06**

** $p \leq .001$.

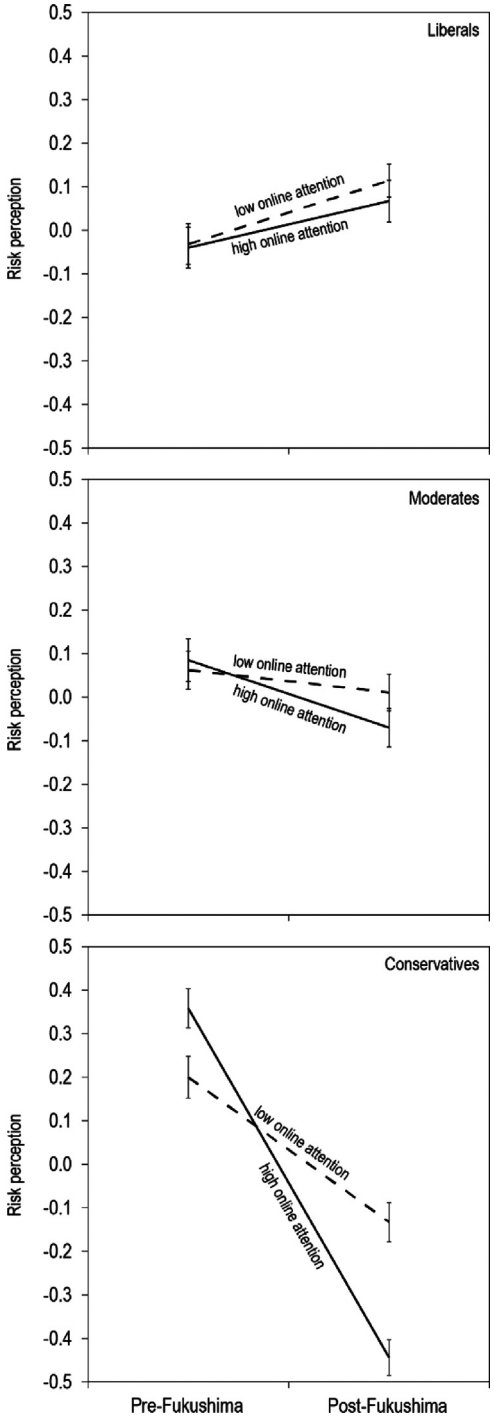

Fig. 3. Interactive effect of ideology, media use, and the Fukushima disaster on public risk perceptions ($N=5000$). Note: *Y*-axis is only partially displayed; error bars indicate standard error.

events in Japan differently, but that these effects are more pronounced among heavy consumers of media.

5. Discussion and conclusions

This study explored public risk perceptions of nuclear power before and after the Fukushima Daiichi disaster in Japan. Specifically, we were interested in examining differences in risk perceptions based on political ideology and media use patterns. Our analysis revealed that liberals and conservatives processed the events in Japan differently, and that such ideological effects were dependent on levels of media attention. However, prior to elaborating on these results, we discuss some limitations of the current work.

First, although we relied upon two coordinated data collections for these analyses, these are not panel data. Therefore, we were unable to examine shifts in risk perceptions in the same group of respondents across time. Rather, our work explores differences in risk perceptions in the aftermath of Fukushima based on relevant grouping characteristics (in this case, political ideology and media attention). This is hardly surprising, of course, as it was impossible to predict that such a major nuclear disaster would occur as we prepared our initial data collection. Rather, we were fortunate to have collected data on nuclear power preceding the events in Japan.

Second, the pre- and post-Fukushima datasets differed slightly in their measurement of risk and benefit perceptions. The pre-Fukushima survey asked respondents a set of items about nuclear power risks and benefits that were averaged into a pair of indices, while the post-Fukushima survey relied on single-item measures for these variables. It is reasonable to assume, however, that any potential random error in our single-item measures would serve to weaken the relationships found in our regression models. Therefore, had we been able to use multi-item measures of risks and benefits in the post-Fukushima dataset, the relationships observed in our regression model would likely have been amplified.

In addition, to examine differences in risk perceptions across the two datasets, we transformed our dependent variables in order to make them comparable. To achieve consistency between our measures of risk and benefit perceptions, we similarly transformed our measures of benefit perceptions. Risk and benefit perceptions in the pre-Fukushima dataset were measured on a 10-point Likert-type scale, while in the post-Fukushima data, these were measured on a 7-point scale. Since the 7-point scale has a true mid-point while the 10-point scale does not, and because we are interested in absolute shifts in risk as opposed to shifts in risk from the sample mean, we chose to trichotomize these variables instead of centering them. We trichotomized our measures prior to residualizing and merging, creating risk perception variables that classified respondents into 'Low', 'Medium,' or 'High' categories. In this case, reducing the level of measurement to a trichotomy leads to a loss in statistical power, which again suggests that our analysis is likely underestimating the strength of the observed relationships. In addition, the residualization left respondents with a unique value on our risk and benefit perception measures that increased variance beyond that of a traditional three-category measure. Therefore, we are confident that creating trichotomized risk and benefit perception variables did not significantly bias our results or produce false positives.

Third, our analysis relied on cross-sectional data. We recognize and acknowledge that cross-sectional data cannot assign a direction of causality to observed phenomena. For example, it may be that perceptions of risk post-Fukushima drove people to consume more media rather than the other way around. In fact, it is most likely a reciprocal process where media attention influenced risk perceptions and risk perceptions, in turn, impacted attention to media. Nevertheless, communication research has convincingly established that media serve as a major drivers of science and risk perceptions, rather than the other way around (Friedman et al., 1986; Nelkin, 1995), thereby increasing our confidence in the direction of causality associated with our interpretation of these findings.

With these considerations in mind, this study make a series of important contributions to the literature. First, this is one of only a small number of studies to empirically examine risk perceptions toward nuclear power in the wake of Fukushima. Moreover, it is the first to do so in the United States with a representative sample.

Second, our analysis is not limited to a single cross-sectional snapshot in time. Instead, we compare attitudes in the months prior to the events in Japan to attitudes in the months following the disaster. Such an approach allows us to garner an understanding of the effects of the disaster on American public opinion of nuclear energy. For example, our findings showed that levels of media attention predicted risk perceptions in the aftermath of Fukushima differently. Among those who paid relatively little attention to news, risk perceptions were significantly higher after the disaster. Conversely, risk perceptions of those who paid comparably higher levels of attention to news decreased significantly in the aftermath.

Third, based on the timing of our post-Fukushima data collection, we can say with some confidence that the impacts of the event have been enduring. Our post-Fukushima survey was conducted nine months after the tsunami crippled the power plant and yet we still find strong impacts on risk perceptions. Previous work has noted that the salience of mediated messages plays a key role in risk perception, and the availability heuristic has been offered as an explanation for the inverse relationships between risk perception induced by exposure to a nuclear risk message and time (Engelberg and Sjöberg, 2005; Tversky and Kahneman, 1974). At first glance, our results appear to represent a departure from those studies.

To investigate this possibility, we relied upon LexisNexis to conduct searches of nuclear energy in newspapers, television, and the Internet using a keyword string[8]. To gauge print coverage we searched large-circulation U.S. newspapers. Our television search relied upon the same search string, but looked at coverage in major television news organizations, such as ABC News, Fox News Network, and MSNBC. Finally, to gauge online coverage we searched the LexisNexis "Web Publications Combined" database. Of course, this examination is far from a comprehensive overview of media coverage of nuclear energy. Most notably, we used a simple keyword search string, the volumes across the different mediums are not directly comparable given the different populations that LexisNexis provides, and this analysis provides no indication of the valence of the content news consumers are likely to encounter. However, it does provide some indication of the volume of coverage to help clarify some of our findings.

This analysis can be found in Fig. 4, which shows that newspaper, television and online media coverage of nuclear power decreased considerably in the weeks and months following the disaster, but remained at comparatively high levels through the end of the calendar year. This is especially noticeable for print and online coverage, where the volume of news stories mentioning "nuclear energy" or "nuclear power" were often at levels twice as high as those recorded in the months before the events in Japan. These relatively high levels of coverage for the remainder of 2011 likely served to keep the issue salient for several months after the initial tsunami hit, and may also explain why we observed lingering impacts on public risk perceptions.

Perhaps most importantly, this study goes beyond a mere examination of risk perceptions at the aggregate level and provides evidence of differential processing among sub-populations. Specifically, we found decreases in the risk perceptions among conservatives in the months following the disaster. Although it is surprising that risk perceptions of liberals did not increase, it may be that there was a ceiling effect. Risk perceptions among liberals may already have been high enough that the accident did not change these. In addition to ideology, we found evidence that the use of media by these ideological groups played a key role in determining risk evaluations. In particular, conservatives who paid

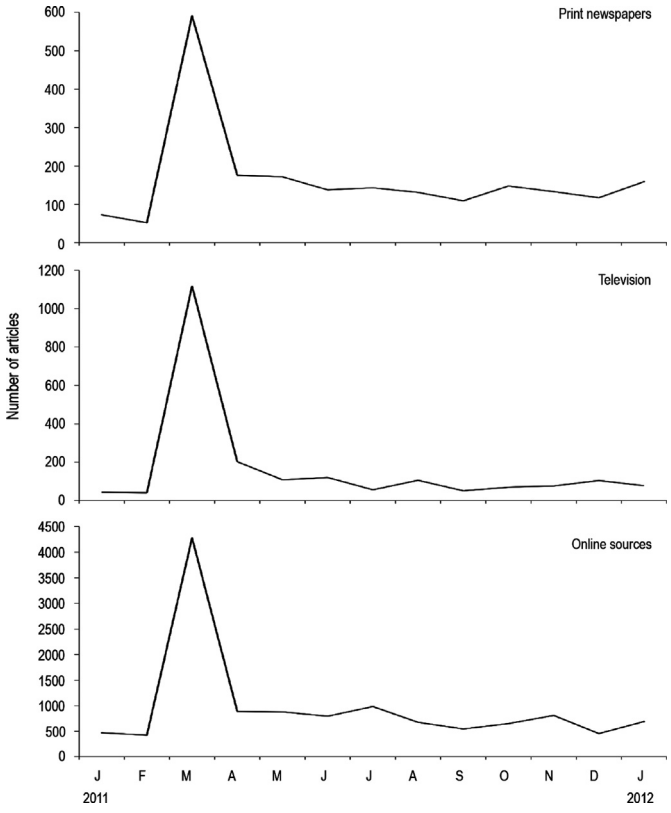

Fig. 4. The volume of nuclear energy coverage in print newspapers, television and online sources.

close attention to media saw major decreases in risk perceptions, while conservatives who paid little attention experienced much smaller drops in their risk perceptions. In this case, instead of media reinforcing political ideology (Lazarsfeld et al., 1948), conservatives appeared to experience a conversion in risk perceptions, possibly due to the content of media coverage that they opted to view.

Selective exposure to certain types of media content by partisan groups in the weeks and months following Fukushima is one potential explanation for the conversion in risk perceptions observed among conservatives with relatively high levels of media use. That is, conservatives may be turning to media content that they expect to confirm their ideological leanings on issues. While liberals may have turned to news organizations with a decidedly anti-nuclear slant, conservatives may have been more inclined to learn about Fukushima from sources that typically support the nuclear industry. Although conservative risk perceptions of nuclear power were relatively high prior to the accident, this may be due more to their inclination to challenge the Obama administration, who were supportive of nuclear energy prior to the accident (e.g. Wald, 2010). Following the accident, coverage in conservative-leaning outlets may have reverted to a pro-nuclear slant.

Indeed, a recent analysis of Fukushima media coverage in the United States and Canada lends some support to our claim of media selectivity. One study found that Fox News was less balanced in assessing the crisis when compared to stations such as ABC and CBS, with Fox News coverage typically downplaying the risks and treating the event as less severe relative to Chernobyl (Katchanovski, 2012). Yet another content analysis of media coverage of the disaster found that news about Fukushima was framed mostly as a "conflict of experts and officials' opinions" (Lazic, 2013, p. 31). As a result, journalists found that the contrary positions held by experts made it difficult for them to assess the information. Nevertheless, future research should pursue content analyses

[8] Nuclear energy OR nuclear power.

comparing coverage across mediums in order to provide a better understanding of media impacts in the aftermath of the disaster event.

Our findings may also be explained by partisan processing of mediated information. Even if individuals with differing political ideologies ended up encountering the same news information, they may have attended to that information differently. For example, information about the failures of the regulatory agency in Japan or the potential negative environmental consequences of the disaster may have resonated particularly well with liberals. As such, they may disproportionately remember that information and give it greater weight when evaluating nuclear energy as a whole. Alternatively, conservatives may have attended more to information about the differences in nuclear safety between the United States and Japan. As a result, they may actually feel reassured that such a disaster is highly unlikely to happen in the U.S. Again, future work is needed to investigate these possibilities.

6. Policy implications

Our results have important implications for both risk communicators and the future of the nuclear industry in the U.S. The results suggest that disaster events, rather than leading to a mainstreaming effect whereby partisan factions become closer in their evaluations of the nuclear industry, can actually serve to further polarize opinions between these groups. Notably, media coverage can exacerbate these effects. This suggests that heavy consumers of media, rather than becoming more informed and uniform in their opinions, become more divided as disasters and their related issues are covered in newspapers, television and the Internet.

Ultimately, public policy in a democratic society is dependent on public input and, to a certain extent, consensus among a majority. Our results highlight that media communications about disasters can further polarize risk perceptions among different groups of citizens, thus driving the partisan wedge deeper and obstructing policy decisions regarding issues such as nuclear energy. Of course, it is important to note that this polarizing effect was observed several months following the disaster at Fukushima, rather than in the immediate aftermath of the event. It may be that partisan groups are less able to integrate dissonant information with their existing attitudes and opinions immediately following a disaster event, particularly given high levels of media coverage. Therefore, it would be interesting to see if the polarization effects outlined in this study were present in the immediate aftermath of the nuclear disaster. Indeed, the Pew data cited earlier noted decreases in support for nuclear power among both Democrats and Republicans in the days and weeks following the start of the meltdowns (Pew Research Center, 2011a), which suggests more universal negative impacts of the event on public opinion. Such information could shed light on the most opportune time to galvanize policy change following a disaster event.

In addition, future research should attempt to garner a better understanding of media impacts surrounding the Fukushima nuclear disaster. For instance, qualitative interviews regarding how people learned about the disaster and where they turned for safety information would provide valuable insights into the mechanisms behind the findings reported here. We have speculated that conservatives and liberals may have turned to different sources when gathering information about Fukushima; however, we were unable to test this empirically. Qualitative interviews coupled with a content analysis of media coverage would prove especially helpful in elucidating the relationships between ideology, media attention, and risk perceptions. For example, how did American audiences view the tone of coverage in U.S. media? And, how did this tone differ across sources? Finally, future research should attempt to replicate these findings in other countries. For example, it would be interesting to know how different groups responded to, and processed media information about the event in a country like France, where more than 75 percent of the electricity is produced via nuclear power. Of course, we realize that we were fortunate to have data that allowed us to conduct the present study, and that such an undertaking may not be possible because of the lack of availability of data.

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