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ARTICLE

Smoke management of wildland and prescribed fire: understanding public preferences and trade-offs

Jarod J. Blades, Steven R. Shook, and Troy E. Hall

Abstract: Smoke from forest fires is a serious and increasing land management concern. However, a paucity of information exists that is specific to public perceptions of smoke. This study used conjoint analysis, a multivariate technique, to evaluate how four situational factors (i.e., smoke origin, smoke duration, health impact, and advanced warning) influence public tolerance of smoke in the northern Rocky Mountains and south-central United States. Separate analyses were performed for subgroups, based on community type, level of fire preparedness, demographics, and smoke experience, to explore potential differences among managerially relevant populations. Origin of the smoke and advanced public warning were commonly the most important factors influencing public tolerance of smoke. A comparison of our conjoint approach with a univariate rating technique is also discussed. Findings from this research will help fire managers understand public tolerance of smoke from forest fires, inform forest management, and enhance public communication strategies.

Key words: tolerance, preference, warning, fire, public, health.

Résumé : La fumée produite par les feux de forêt est une préoccupation sérieuse et grandissante en aménagement du territoire. Cependant, il existe peu d'information spécifique au sujet de la perception de la fumée par le public. Dans cette étude nous avons eu recours à l'analyse conjointe, une technique d'analyse multivariée, pour évaluer de quelle façon quatre facteurs conjoncturels (c.-à-d. origine de la fumée, durée de la fumée, impact sur la santé et alertes précoces) influencent la tolérance du public à la fumée dans les Rocheuses du Nord et le centre-sud des États-Unis. Des analyses distinctes ont été effectuées pour des sous-groupes sur la base du type de communauté, de l'état de préparation en cas de feu, des caractéristiques démographiques et de l'expérience face à la fumée pour explorer les différences potentielles parmi les populations pertinentes du point de vue de l'aménagement. L'origine de la fumée et les alertes précoces étaient communément les facteurs qui influençaient le plus la tolérance du public à la fumée. Une comparaison de notre approche conjointe avec la technique de cotation univariée fait également l'objet d'une discussion. Les résultats de cette étude aideront les gestionnaires du feu à comprendre la tolérance du public à la fumée produite par les feux de forêt, à informer les aménagistes forestiers et à améliorer les stratégies de communication avec le public. [Traduit par la Rédaction]

Mots-clés : tolérance, préférence, avertissement, feu, public, santé.

Introduction

Smoke from forest fires can result in public controversy and impair forest management when it disperses over residential, commercial, recreational, and transportation areas. Many North Americans are experiencing impacts from forest fire smoke due to increases in wildfire activity and more people living in the wildland–urban interface (WUI) and rural areas (Hammer et al. 2009). Smoke is a particularly salient concern because it can create short- and long-term health problems, notably for smoke-sensitive populations, including children, the elderly, and those with existing health conditions (Environmental Protection Agency 2008). Clearly, there are many ways that smoke from wildland fires can negatively impact residents at individual, community, and regional levels.

In the center of these issues are land managers, who are tasked with the additional challenges of navigating changing land management priorities and regulatory restrictions (Haines et al. 2001). Specifically, air quality regulations in the United States (US) have been tightening during a time when forest fuel reduction projects and prescribed (Rx) burning are in great demand. Lowering National Ambient Air Quality Standards (NAAQS) has created new nonattainment areas (especially near national forests, parks, and wildlife refuges), increased challenges for conducting Rx fires, raised the number of air quality violations, and expanded the administrative and planning workloads for wildland fire management agencies (Riebau and Fox 2010). Thus, managers face considerable challenges in meeting forest health and air quality standards concurrently.

Understanding the diverse public opinions toward smoke from wildland and Rx fires is important for managers and public officials, yet a paucity of research has been conducted on this topic. This study, funded by the US Joint Fire Science Program, aimed to understand the factors that underlie public tolerance of smoke from fires. This paper uses conjoint analysis and compares a univariate rating method to understand how context-specific factors and trade-offs affect public tolerance of smoke from forest fires.

Study areas and communities

This study focused on two regions: the US northern Rocky Mountains (Idaho and western Montana; NORO) and the south-central US (east Texas and western Louisiana; SOUTH). In both regions, forest health concerns, increases in wildfire activity, and

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changing social dynamics have resulted in wildland fire and smoke issues not present in the past (USDA Forest Service 2009). Many communities historically reliant on resource commodities (e.g., logging, ranching, and agriculture) have been transitioning towards amenity-based economies (Winkler et al. 2007). Both regions have experienced amenity-driven population and housing growth and greater population redistribution into WUI areas (Hammer et al. 2009). Though there are some similarities, there are also important variations between the two regions such as fire return intervals, the type and amount of Rx fire use, size of metropolitan areas, and ethnicity.

US northern Rocky Mountains

This region has been experiencing rapid ecological changes such as increased fuel loading, tree mortality, higher potential for insect establishment and spread, and subsequently larger and more severe wildfires and smoke levels (Morgan et al. 2008; Westerling 2008; Westerling et al. 2006). Increases in both wild and Rx forest fires in the region will clearly result in more frequent human exposure to smoke.

Every county in Idaho and Montana has completed a County Wildfire Protection Plan (CWPP), but the level of "actual" preparedness for fire varies greatly by community. For example, many CWPPs were written prior to the passage of the Healthy Forests Restoration Act of 2003 and some have not been updated to comply with the CWPP guidelines stipulated in the Act. Other factors affecting community preparedness for fire include the level of coordination between wildfire and structural fire fighters, paid versus unpaid volunteer firefighters, presence of a WUI committee, and amount of funding obtained for fuel reduction projects. These factors were taken into consideration when selecting and classifying each community as urban non-WUI (non-WUI), WUI more-prepared (WUIMP), or WUI less-prepared (WUILP).

South-central US (east Texas and western Louisiana)

Rx burning in south-central forests has been a regular annual occurrence to address increased fuel loads, primarily near communities at risk. In general, residents in the south-central US have more experience with Rx fire and associated smoke than other parts of the country because the practice is more commonly used and accepted on federal, state, and private lands in this region — even in the presence of increasing constraints from urban expansion, air quality regulations, and liability for smoke intrusions and escaped fires (Fried et al. 2006; Haines et al. 2001). Nevertheless, smoke resulting from Rx burning is a primary concern for land managers and community residents alike.

This concern will increase with climate change. Gulf Coast states are anticipated to be affected by climate change in the form of less rainfall in winter and spring, and the frequency, duration, and intensity of droughts are likely to continue increasing (Karl et al. 2009). More intense wildfires have accompanied the increases in temperatures, drought, southern pine beetle outbreaks, and erratic weather. Similar to the NORO, increases in amenity migration into the WUI, coupled with more frequent wild and Rx fires, will lead to more instances of people experiencing impacts from smoke.

Methods

Why use conjoint analysis?

Conjoint analysis was developed to understand how respondents develop preferences for any type of complex object, specifically what trade-offs each person is willing to make among the attributes of the object (Hair et al. 2010). It is based on the assumption that people develop preferences by combining separate pieces of a particular scenario. For example, when considering the purchase of a chainsaw, one might focus on the key attributes of cost, brand, size, chain specifications, and warranty. Before purchasing the saw, it may seem that brand and size are the most important attributes in a chainsaw. However, after obtaining information about different models and learning how expensive chainsaws are, one might focus more on cost and warranty than brand and size. Thus, when looking at the chainsaws, one is making simultaneous trade-offs about the choice that may, or may not, match what was originally considered as preferable prior to learning about the actual possibilities available.

In contrast to conjoint approaches, typical multivariate studies have participants rate attributes individually, often using these ratings in regression models that "compose" the association between independent variables and a dependent variable (e.g., choice of chainsaw). However, people are not always able to reliably weight the separate features of a complete scenario, and they may say that all attributes are important, ignoring the fact that actual options often cannot maximize all desirable features simultaneously (Orme 2005).

In this study, conjoint analysis was used to understand public tolerance of smoke from forest fires based on different attributes that occur when a person experiences smoke from a wildland or Rx fire. Similar to the chainsaw example, when considering aspects in isolation, one might consider health impacts to be the most important attribute influencing tolerance of smoke; however, other variables may rise to greater level of importance (e.g., the source of the smoke or advanced warning prior to a Rx fire) when considering a whole scenario where trade-offs are required. The conjoint approach presented here required study participants to evaluate complete and realistic smoke scenarios comprised of multiple contextual variables simultaneously, which were then "decomposed" to estimate the independent variable preference structure.

Given the exploratory nature of conjoint analysis in studies in the natural resources domain, we compared a univariate rating task with our multivariate conjoint task to determine whether the two approaches yield similar findings. Previous studies have contrasted conjoint techniques with univariate tasks and found mixed results. Several studies from the health field have found that conjoint and univariate tasks yielded similar results for the most important attribute (e.g., Bridges et al. 2012), but the order of importance of other attributes varied considerably across studies (Pignone et al. 2012). Other heath studies have found differences between conjoint analysis and Likert-type univariate ratings, where conjoint analysis was more effective at describing the magnitude of differences between the attributes (Johnson et al. 2006; Ryan et al. 2001). To our knowledge, this study represents the first comparison between univariate and conjoint techniques in a natural resources setting.

Key variables in the context of smoke

Our primary consideration in constructing the scenarios was the selection of key contextual factors likely to influence opinions about whether or not the smoke from forest fire is tolerable (Hair et al. 2010; Louviere et al. 2000). For example, smoke that lasts a few hours from a lightning-caused wildfire may be considered more tolerable than smoke that lasts 24 h from a Rx fire. It was also crucial to use the fewest possible factors to reduce participation burden. The factors used in this study were carefully selected based on consultation of several sources, including (*i*) recommendations from collaborating smoke researchers, (*ii*) existing research on key factors that influence public opinions about forest fire, (*iii*) previous conjoint studies related to natural resources and fire (e.g., Kneeshaw et al. 2004), and (*iv*) pilot testing with three undergraduate classes at a university in 2011. Four key factors (fire origin, advanced warning, smoke duration, and health effects) were identified from these sources and explored for their influence on public tolerance of smoke from wildland fire (Table 1). Several other factors were considered at the beginning of the process (e.g., fire management strategy, forest recovery, and outdoor recreation impact) but were eliminated or subsumed by

Table 1. Attributes and levels used for the conjoint survey questions.

Attribute	Levels
Fire origin	Wildfire (lightning caused or unintentional) Prescribed-natural fire (wildland fire use) Prescribed fire
Smoke duration in community	Up to 6 h Up to 2 days Longer than 2 days
Health effects	Moderate (extremely sensitive individuals may experience respiratory symptoms) Unhealthy for sensitive groups (increasing likelihood of respiratory symptoms and breathing discomfort in sensitive groups) Very unhealthy for everyone (substantial risk of respiratory effects in the general population)
Advanced warning	None (no advanced warning) Public service announcement (a message is broadcasted on the local radio or TV news, or in the local newspaper) Personal phone call (agency personnel give you a call)

other factors (e.g., smoke intensity and visibility merged into health effects) based on feedback during the selection process.

Research has shown that the “origin of a fire” can influence public support for fire management practices (Gardner et al. 1985; Kneeshaw et al. 2004) and tolerance of the resulting smoke (Weisshaupt et al. 2005). Forest fires are ignited by lightning or by humans. Human-caused ignitions may occur by accident or carelessness (e.g., escaped campfire, sparks from vehicles, or arson), or they may be ignited intentionally and contained by forest managers to achieve forest health objectives (i.e., Rx fire). Forest managers may also choose to allow lightning-caused fires to burn (rather than suppress them) to achieve forest health objectives, which is called prescribed-natural fire, management-ignited fire, wildland fire use, or wildland fire management. We asked respondents to consider the origin of a fire when deciding how tolerant they are of smoke.

Previous research has suggested that the frequency and magnitude of seasonal fire activity can be a driving influence in regional differences in support for Rx fire practices (Loomis et al. 2001). It was intuitive that the duration of time that a person has been exposed to smoke (i.e., “smoke duration”) would influence tolerance of smoke. The duration of smoke exposure can have cascading effects related to public health, recreation and tourism, school activities, and transportation.

The potential “health effects” from smoke were suspected to be strongly related to smoke tolerance. Kneeshaw et al. (2004) found that respondents living within or near three western US national forests rated air quality concerns (i.e., health) as a consistent factor for supporting full suppression of fires. In a Florida study, the majority of respondents said that protecting air quality (i.e., health) was more important than the ecological benefits of Rx burning. A review of four studies by McCaffrey (2006) found that up to 30% of respondents lived in a household where a member had a health issue that could be affected by smoke. Clearly, health effects are an important consideration for public tolerance of smoke.

Focus groups conducted by Olsen et al. (2014) identified the importance of “advanced warning” when discussing smoke-related impacts. There has been a recent call for a better understanding of public perceptions of advanced warning systems related to natural hazards such as hurricanes and fires (Gladwin et al. 2009; Joint Fire Science Program 2013). To our knowledge, this topic has never been explored in relation to the acceptability of fire management or tolerance of smoke. Advanced warning systems alert individuals and communities about the potential threat of smoke in order for them to act in sufficient time and in an appropriate manner to reduce the possibility of injury, loss of life, property damage, and loss of livelihoods (Bridge 2010).

In this study, we also compared tolerance of smoke across regions (northern Rocky Mountains and south-central US), the level of community preparedness for wildland fire, urban or rural residents, gender (men, women), and whether the respondent had experienced previous adverse health effects from smoke from wildland fire (Health — yes, Health — no).

Sampling design

A quantitative design was chosen based on a desire to generalize findings to the populations of the study regions (Creswell 2009). Communities from the NORO and SOUTH were stratified into three types (selection process described further below): (1) wildland–urban interface (WUI) communities that are more prepared for fire (WUIMP); (2) WUI communities that are less prepared for fire (WUILP); and (3) urban areas not located in the WUI but that have a high potential to be impacted by smoke (non-WUI). Communities were selected through a review of CWPP literature in each county of the two regions, consultation with local land and fire managers to discuss communities that met each classification, and a web-based exploratory questionnaire of more than 200 fire managers, land managers, and community leaders asking them to nominate communities.

We desired to obtain a random sample of 200 completed questionnaires from each of the 18 communities (i.e., 3600 total completed questionnaires). This minimum sample size was necessary to satisfy the recommendations for conjoint analysis (see Measurements and Data Analysis below) (Hair et al. 2010; Orme 2005). We purchased 12 000 names, addresses, and phone numbers from Survey Sampling International, Orem, Utah.

We followed a modified version of Dillman's total design method (Dillman et al. 2009) to ensure maximum participation. An initial letter was mailed to participants notifying them about the study and providing an internet address where they could complete the questionnaire online. A reminder postcard was sent 15 days after the initial mailing. A physical questionnaire was mailed three weeks later to anyone who had not completed the questionnaire online. Participants were enrolled in a lottery for one of six $250 gift certificates as an incentive for completing the questionnaire. We conducted 50 telephone interviews with randomly selected nonrespondents in each region (100 in total) to assess potential bias between responders and nonresponders (Creswell 2009). Nonrespondents were asked about their support for Rx fire practices, opinions about the potential outcomes of Rx

Table 2. Summary of sample characteristics by region, community preparedness, urban or rural, gender, and prior experience with health effects from forest fire smoke.

	Responses	No variance	Missing values	Skipped question	Total removed	% Total removed	Usable sample
NORO							
Region total	1542	119	85	205	409	26	1133
non-WUI	481	28	21	40	89	19	392
WUIMP	502	26	21	52	99	20	403
WUILP	556	39	21	64	124	22	432
Urban	1243	70	50	118	238	19	1005
Rural	296	23	13	38	74	25	222
Men	1085	62	37	102	201	19	884
Women	397	26	12	54	92	23	305
Health — Y	442	35	14	58	107	24	335
Health — N	1100	58	49	98	205	19	895
SOUTH							
Region total	375	26	22	48	96	26	279
non-WUI	110*	—	—	—	—	—	—
WUIMP	120*	—	—	—	—	—	—
WUILP	145*	—	—	—	—	—	—
Urban	163*	—	—	—	—	—	—
Rural	212	2	7	14	23	11	189
Men	243	17	10	30	57	23	186
Women	102*	—	—	—	—	—	—
Health — Y	48*	—	—	—	—	—	—
Health — N	327	21	18	38	77	24	250

Note: NORO, northern Rockies sample; SOUTH, south-central sample; non-WUI, communities not located in the wildland–urban interface; WUIMP, WUI communities that were more prepared for fire; WUILP, WUI communities that were less prepared for fire; Health — Y, respondents that had previously had an adverse health impact from smoke; Health — N, respondents that had not previously had an adverse health impact from smoke. No variance meant that the respondent answered each conjoint scenario question with the same rating value, resulting in no variance to analyze. Missing values meant that the respondent failed to answer one or more of the conjoint scenario questions, failing to meet the nine-scenario minimum. Skipped question meant that the respondent did not provide any answers for the conjoint scenario questions. The usable sample value was the amount of responses carried forward for conjoint analysis for each grouping.

*Groupings that had fewer than 200 responses did not meet the minimum sample size recommendation for conjoint analysis and were not carried forward.

fire, tolerance of smoke from Rx fire, and demographic characteristics.

We received 1538 completed questionnaires in the NORO for an overall response rate of 28%. Approximately one-quarter of the respondents in each subgroup were removed from the analysis because they did not answer one or all of the conjoint scenario questions (failing to evaluate the minimum number of nine scenarios) or provided the same rating value for all of the scenarios, resulting in no variance to evaluate (Table 2). In the SOUTH, the smaller usable sample (n = 375, response rate of 6%) resulted in many of the groups failing to meet the recommended minimum of 200 responses for conjoint analysis and subsequently being dropped from analysis due to unreliable parameter estimates. Conclusions and comparisons drawn from the SOUTH sample are therefore only discussed at the regional level.

In both regions, no significant differences were found between the responders and nonresponders regarding their support for Rx fire practices, opinions about the potential outcomes of Rx fire, or tolerance of smoke from Rx fire. In both regions, respondents were more educated than nonresponders, and in the south, respondents were significantly more likely to be permanent residents than were nonresponders. Overall, these findings indicated that respondents in each region had similar opinions and characteristics as their population.

Conjoint measurements

A variety of formats is used for conjoint studies, including rating, ranking, and choice-based methods — each with its own distinct advantages and disadvantages (Hair et al. 2010; Louviere et al. 2000). For this study, we used a rating method in which respondents were presented with combinations of fire and smoke attributes and are asked to rate their tolerance of each scenario. We selected the rating method to reduce participant burden and to promote more careful consideration of each scenario and its associated attributes (Louviere et al. 2000). Each participant's self-reported smoke tolerance was directly measured for each conjoint scenario on a seven-point Likert-type scale of tolerance (–3 (very intolerant) to +3 (very tolerant); Fig. 1).

We used an orthogonal fractional factorial design for this survey, meaning that each attribute and level was independent and that only a subset of the possible scenario combinations was used (Hair et al. 2010). The basic model of this conjoint analysis was additive and linear, meaning that smoke tolerance was assumed to be the sum of each attribute, with a linear relationship between the attribute levels and smoke tolerance.

The fractional subset of fire and smoke scenarios was generated from the 81 total potential scenarios (full factorial) using SPSS Conjoint, version 10, and was an optimal design, meaning that it was orthogonal and balanced the same number of levels per factor. Hair et al. (2010) suggest the number of scenarios to be evaluated by each survey respondent should be calculated as follows:

$$\text{Minimum scenarios} = \text{total number of levels across all factors} - \text{number of factors} + 1$$

Based on the above equation, each respondent evaluated nine scenarios. A full-profile method was used to create each scenario, meaning that each scenario used one level from each attribute.

Fig. 1. Example from the survey that shows the four attributes comprising a full scenario and the tolerance rating scale.

Smoke Scenario 1

- There is no advanced warning about anticipated smoke

- The smoke is from a prescribed-natural fire

- The smoke would be very unhealthy for everyone (see picture 3 on separate included page)

- The smoke will be present for up to 2 days

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

The most important aspect of a full-profile task is that it encourages respondents to evaluate each scenario individually (Huber, 1997).

We found that realistically depicting the fire and smoke scenarios verbally was challenging; therefore, a representative and standardized series of real images of varying smoke levels was included in each survey. All other attributes were described in a textual format.

Data analysis

Each respondent was analyzed separately, and the utility scores were viewed for each respondent and aggregated into community types and regions (Hair et al. 2010). Model goodness of fit was evaluated for each individual using the Pearson's correlation coefficient between observed and expected tolerance. The respondent's tolerance of smoke was assessed by calculating the mean utility scores for each level of the attributes: fire origin, advanced warning, smoke duration, and associated health effects. The magnitude and polarity (positive or negative) of each utility score indicated the relative influence of each attribute level on the mean smoke tolerance ratings. For example, the positive utility scores associated with fires that originated from lightning indicated that the attribute level increased the respondent's overall mean tolerance of smoke (constant + level utility score). Conversely, the negative utility scores associated with Rx fire indicated that the factor level decreased the respondent's mean tolerance of smoke (constant – level utility score). Utility scores can be added together (plus the constant) to determine the predicted smoke tolerance rating. Relative importance scores were computed by calculating the range of utility scores for each attribute and then dividing it by the total range in utility values across all attributes (Hair et al. 2010). Paired sample t tests were used to evaluate differences in mean acceptability ratings between the levels of each attribute.

Conjoint analysis was conducted separately and compared by region (NORO and SOUTH), level of community preparedness for wildland fire (non-WUI, WUIMP, WUILP), urban or rural, gender (men, women), and whether the respondent had experienced previous adverse health effects from smoke from wildland fire (Health — yes, Health — no).

Results and discussion

Utility scores of the attribute levels

Overall, respondents from both regions and all groups were somewhat tolerant to very tolerant of smoke from forest fires (range of the mean constant values was from 1.14 to 2.12). All mean tolerance ratings were positive values, except one, among respondents who had previously experienced a negative health effect from smoke and the smoke levels of the scenario would be unhealthy for everyone (NORO m = −0.05, total m = −0.07, slightly intolerant). This is consistent with previous findings that smoke from forest fires is not a major concern for the majority of the public (Blanchard and Ryan 2007; Brunson and Shindler 2004; Shindler and Toman 2003) but can be a salient issue for individuals who have an existing health condition that is aggravated by smoke (e.g., asthma or heart disease) or have experienced a previous smoke impact to their health (McCaffrey 2006; McCaffrey and Olsen 2012).

All mean differences between levels of each attribute were statistically significant ($p < 0.01$; Tables 3 and 4), meaning that participants, on average, discerned differences between the levels of each attribute. The respondents' preference structures related to fire origin, advanced warning, smoke duration, and health effects were surprisingly similar between both regions and among all other groupings (Tables 3 and 4). For example, the only significant differences between the two regions were related to the source of the smoke. Residents in the NORO were slightly, though significantly, more tolerant of smoke from lightning-caused fires than residents of the SOUTH (NORO m = 2.45, SOUTH m = 2.12), and residents of the SOUTH were slightly more tolerant of smoke from Rx fires than residents of the NORO (NORO m = 1.36, SOUTH m = 1.45). In both regions, respondents were significantly more tolerant of smoke that came from lightning-caused fires (overall m = 2.40) than smoke from prescribed-natural (overall m = 1.69) or Rx fires (overall m = 1.40). This is contrary to previous work by Weisshaupt et al. (2005), who conducted focus groups in Spokane, Washington, and Missoula, Montana, and found that participants were more accepting of smoke from Rx fires than smoke from lightning-caused wildfires. The discrepancy between the Weisshaupt et al. findings and our study could be due, in part, to data collection methods (focus group deliberations with a self-selected sample versus a large representative regional public survey) and participant bias due to previous smoke experience (i.e., in Weisshaupt et al.'s study, some focus group participants had experienced substantial wildfire smoke during the previous summer and viewed Rx forest burning as an effective fuels reduction technique that reduced catastrophic wildfire risk and smoke). Our study, with a regional and random sampling approach, is likely more representative of the public's greater tolerance of smoke from lightning-caused wildfires than smoke from Rx and prescribed-natural fires. Lightning-caused fires are a natural occurrence in which the responsibility for smoke cannot be attributed to human management decisions, which likely explains higher public tolerance of the resulting smoke. Moreover, people recognize that often little can be done to reduce smoke from these fires. Conversely, smoke from Rx and prescribed-natural fires is the result of a deliberate management decision, which provides a target for public frustrations and blame related to smoke impacts. Regardless, we found that the public is generally tolerant of smoke from forest fires, irrespective of the source, which mirrors the findings of previous research (Blanchard and Ryan 2007; Brunson and Shindler 2004; Shindler and Toman 2003).

Table 3. Tolerance of smoke utility scores and mean ratings by region and community preparedness.

		Region total		non-WUI		WUIMP		WUILP	
Attribute	Level	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating
NORO									
Fire origin	Natural (lightning or unintentional)	0.62	2.45	0.63	2.63	0.60	2.52	0.61	2.29
	Prescribed-natural (wildland fire use)	–0.15	1.68	–0.16	1.84	–0.13	1.79	–0.15	1.53
	Prescribed fire	–0.47	1.36	–0.48	1.52	–0.48	1.44	–0.46	1.22
Advanced warning	None	–0.54	1.29	–0.62	1.38	–0.54	1.38	–0.48	1.20
	Public service announcement	0.13	1.96	0.16	2.16	0.15	2.07	0.10	1.78
	Personal phone call	0.41	2.24	0.46	2.46	0.39	2.31	0.37	2.05
Smoke duration in community	Short — 6 h	–0.33	1.50	–0.29	1.71	–0.35	1.57	–0.34	1.34
	Moderate — up to 3 days	–0.65	1.18	–0.58	1.42	–0.70	1.22	–0.68	1.00
	Long — more than 3 days	–0.98	0.85	–0.86	1.14	–1.05	0.87	–1.03	0.65
Health effects	Moderate	–0.47	1.36	–0.51	1.49	–0.47	1.45	–0.44	1.24
	Unhealthy for sensitive populations	–0.94	0.89	–1.02	0.98	–0.95	0.97	–0.88	0.81
	Unhealthy for everyone	–1.41	0.42	–1.52	0.48	–1.42	0.50	–1.31	0.37
	Constant	1.85		2.00		1.92		1.68	
	Goodness of fit	0.99		0.99		0.99		0.99	
SOUTH									
Fire origin	Natural (lightning or unintentional)	0.39	2.12	—	—	—	—	—	—
	Prescribed-natural (wildland fire use)	–0.11	1.62	—	—	—	—	—	—
	Prescribed fire	–0.28	1.45	—	—	—	—	—	—
Advanced warning	None	–0.60	1.13	—	—	—	—	—	—
	Public service announcement	0.15	1.88	—	—	—	—	—	—
	Personal phone call	0.45	2.17	—	—	—	—	—	—
Smoke duration	Short — 6 h	–0.27	1.45	—	—	—	—	—	—
	Moderate — up to 3 days	–0.55	1.18	—	—	—	—	—	—
	Long — more than 3 days	–0.82	0.91	—	—	—	—	—	—
Health effects	Moderate	–0.51	1.22	—	—	—	—	—	—
	Unhealthy for sensitive populations	–1.01	0.71	—	—	—	—	—	—
	Unhealthy for everyone	–1.52	0.21	—	—	—	—	—	—
	Constant	1.73		—		—		—	
	Goodness of fit	0.99		—		—		—	
TOTAL									
Fire origin	Natural (lightning or unintentional)	0.57	2.40	0.59	2.55	0.58	2.47	0.55	2.23
	Prescribed-natural (wildland fire use)	–0.14	1.69	–0.15	1.81	–0.13	1.76	–0.14	1.54
	Prescribed fire	–0.43	1.40	–0.44	1.52	–0.45	1.44	–0.41	1.27
Advanced warning	None	–0.55	1.28	–0.64	1.32	–0.56	1.33	–0.47	1.21
	Public service announcement	0.14	1.97	0.17	2.13	0.16	2.05	0.09	1.77
	Personal phone call	0.42	2.25	0.47	2.43	0.40	2.29	0.38	2.06
Smoke duration	Short — 6 h	–0.32	1.51	–0.29	1.67	–0.33	1.56	–0.33	1.35
	Moderate — up to 3 days	–0.63	1.20	–0.58	1.38	–0.66	1.23	–0.66	1.02
	Long — more than 3 days	–0.95	0.88	–0.86	1.10	–1.00	0.89	–0.98	0.70
Health effects	Moderate	–0.48	1.35	–0.51	1.45	–0.48	1.41	–0.45	1.23
	Unhealthy for sensitive populations	–0.95	0.88	–1.02	0.94	–0.95	0.94	–0.91	0.77
	Unhealthy for everyone	–1.43	0.40	–1.52	0.44	–1.43	0.46	–1.36	0.32
	Constant	1.83		1.96		1.89		1.68	
	Goodness of fit	0.99		0.99		0.99		0.99	

Note: NORO, northern Rockies sample; SOUTH, south-central sample; TOTAL, combined regions; non-WUI, communities not located in the wildland–urban interface; WUIMP, WUI communities that were more prepared for fire; WUILP, WUI communities that were less prepared for fire. Scale rating for the dependent variable, tolerance of smoke, ranged from –3 (very intolerant) through 0 (neutral) to 3 (very tolerant). The goodness-of-fit statistic is the Pearson's correlation between predicted and observed tolerance ratings. All level values within an attribute are significantly different at the $p < 0.001$ level. Many cells contain dashes because they did not meet the minimum sample size requirement.

Respondents from both regions were clear that advanced warning about potential smoke impacts was important. Respondents preferred a personal phone call warning about smoke ($m = 2.25$) significantly more than a public service announcement ($m = 1.97$) or receiving no advanced warning at all ($m = 1.28$). This finding is consistent with an online nationwide survey pertaining to Americans' greatest public safety concerns, which found that one in four Americans said they would prefer to be notified about an emergency situation by a personal telephone call or by television announcement (Federal Signal 2010). Advance warning systems related to forest fire and smoke have been a topic of increasing interest for the fire management community, as evidenced by a recent call for more research about the effectiveness of public warning and evacuation systems and public perceptions about the need for warning or evacuation systems (Joint Fire Science Program 2013). Our study provides an empirical example from

Table 4. Tolerance of smoke utility scores and mean ratings by urban or rural residence, gender, and prior experience with health effects from forest fire smoke.

		Urban		Rural		Men		Women		Health — Y		Health — N	
Attribute	Level	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating
NORO													
Fire origin	Natural (lightning or unintentional)	0.61	2.45	0.65	2.60	0.61	2.51	0.63	2.46	0.57	1.75	0.63	2.75
	Prescribed-natural (wildland fire use)	–0.14	1.70	–0.19	1.76	–0.14	1.76	–0.17	1.66	–0.15	1.03	–0.15	1.97
	Prescribed fire	–0.47	1.37	–0.46	1.49	–0.48	1.42	–0.46	1.37	–0.42	0.76	–0.49	1.63
Advanced warning	None	–0.54	1.30	–0.52	1.43	–0.53	1.37	–0.61	1.22	–0.46	0.72	–0.58	1.54
	Public service announcement	0.14	1.98	0.12	2.07	0.14	2.04	0.13	1.96	0.12	1.30	0.14	2.26
	Personal phone call	0.41	2.25	0.40	2.35	0.39	2.29	0.49	2.32	0.33	1.51	0.44	2.56
Smoke duration	Short — 6 h	–0.32	1.52	–0.36	1.59	–0.32	1.58	–0.34	1.49	–0.35	0.83	–0.32	1.80
	Moderate — up to 3 days	–0.64	1.20	–0.72	1.23	–0.65	1.25	–0.69	1.14	–0.70	0.48	–0.64	1.48
	Long — more than 3 days	–0.96	0.88	–1.08	0.87	–0.97	0.93	–1.03	0.80	–1.05	0.13	–0.95	1.17
Health effects	Moderate	–0.47	1.37	–0.47	1.48	–0.46	1.44	–0.51	1.32	–0.41	0.77	–0.49	1.63
	Unhealthy for sensitive populations	–0.94	0.90	–0.94	1.01	–0.92	0.98	–1.02	0.81	–0.82	0.36	–0.99	1.13
	Unhealthy for everyone	–1.42	0.42	–1.41	0.54	–1.38	0.52	–1.53	0.30	–1.23	–0.05*	–1.48	0.64
	Constant	1.95		1.84		1.90		1.83		1.18		2.12	
	Goodness of fit	0.99		0.99		0.99		0.99		0.99		0.99	
SOUTH													
Fire origin	Natural (lightning or unintentional)	—	—	0.35	2.06	0.38	2.19	—	—	—	—	0.37	2.24
	Prescribed-natural (wildland fire use)	—	—	–0.10	1.60	–0.13	1.68	—	—	—	—	–0.11	1.76
	Prescribed fire	—	—	–0.25	1.45	–0.25	1.56	—	—	—	—	–0.27	1.60
Advanced warning	None	—	—	–0.53	1.17	–0.63	1.18	—	—	—	—	–0.60	1.27
	Public service announcement	—	—	0.10	1.81	0.19	2.00	—	—	—	—	0.15	2.02
	Personal phone call	—	—	0.42	2.13	0.44	2.25	—	—	—	—	0.45	2.32
Smoke duration	Short — 6 h	—	—	–0.29	1.41	–0.26	1.55	—	—	—	—	–0.28	1.59
	Moderate — up to 3 days	—	—	–0.58	1.12	–0.53	1.28	—	—	—	—	–0.55	1.32
	Long — more than 3 days	—	—	–0.88	0.82	–0.79	1.02	—	—	—	—	–0.83	1.04
Health effects	Moderate	—	—	–0.51	1.19	–0.49	1.32	—	—	—	—	–0.53	1.34
	Unhealthy for sensitive populations	—	—	–1.02	0.68	–0.98	0.83	—	—	—	—	–1.05	0.82
	Unhealthy for everyone	—	—	–1.53	0.17	–1.47	0.34	—	—	—	—	–1.58	0.29
	Constant	—		1.70		1.81		—		—		1.87	
	Goodness of fit	—		0.99		0.99		—		—		0.99	
TOTAL													
Fire origin	Natural (lightning or unintentional)	0.59	2.42	0.53	2.37	0.57	2.45	0.58	2.36	0.57	1.71	0.58	2.64
	Prescribed-natural (wildland fire use)	–0.14	1.69	–0.15	1.69	–0.14	1.74	–0.15	1.63	–0.15	0.99	–0.14	1.92
	Prescribed fire	–0.45	1.38	–0.37	1.47	–0.44	1.44	–0.43	1.35	–0.41	0.73	–0.44	1.62

Table 4 (*concluded*).

Attribute	Level	Urban		Rural		Men		Women		Health — Y		Health — N	
		Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating	Utility	Mean rating
Advanced warning	None	−0.56	1.27	−0.53	1.31	−0.55	1.33	−0.59	1.19	−0.47	0.67	−0.58	1.48
	Public service announcement	0.15	1.98	0.11	1.95	0.15	2.03	0.11	1.89	0.13	1.27	0.14	2.20
	Personal phone call	0.42	2.25	0.41	2.25	0.40	2.28	0.48	2.26	0.34	1.48	0.44	2.50
Smoke duration	Short — 6 h	−0.31	1.52	−0.33	1.51	−0.31	1.57	−0.33	1.45	−0.34	0.80	−0.31	1.75
	Moderate — up to 3 days	−0.62	1.21	−0.66	1.18	−0.63	1.25	−0.66	1.12	−0.68	0.46	−0.62	1.44
	Long — more than 3 days	−0.94	0.89	−1.00	0.84	−0.94	0.94	−0.99	0.79	−1.02	0.12	−0.93	1.14
Health effects	Moderate	−0.48	1.35	−0.49	1.35	−0.47	1.41	−0.52	1.26	−0.40	0.74	−0.50	1.56
	Unhealthy for sensitive populations	−0.95	0.88	−0.97	0.87	−0.93	0.95	−1.03	0.75	−0.81	0.33	−1.00	1.06
	Unhealthy for everyone	−1.43	0.40	−1.46	0.38	−1.40	0.48	−1.55	0.23	−1.21	−0.07*	−1.51	0.55
	Constant	1.83		1.84		1.88		1.78		1.14		2.06	
	Goodness of fit	0.99		0.99		0.99		0.99		0.99		0.99	

Note: NORO, northern Rockies sample; SOUTH, south-central sample; TOTAL, combined regions; Health — Y, respondents that had previously had an adverse health impact from smoke; Health — N, respondents that had not previously had an adverse health impact from smoke. Scale rating for the dependent variable, tolerance of smoke, ranged from −3 (very intolerant) through 0 (neutral) to 3 (very tolerant). The goodness-of-fit statistic is the Pearson's correlation between predicted and observed tolerance ratings. All level values within an attribute are significantly different at the $p < 0.001$ level. Many cells contain dashes because they did not meet the minimum sample size requirement.

*These are the only instances where the mean smoke tolerance rating was a negative value.

two regions of the US of public desire for advance warning systems; this is perhaps one of the most important considerations for public tolerance of smoke and public support for Rx fire management.

Not surprisingly, respondents were more tolerant of briefer rather than longer smoke duration. Smoke present for up to 6 h (the shortest duration) was significantly more preferred (m = 1.51) than smoke that lasted for 3 days (m = 1.20) or longer (m = 0.88). Similarly, and not surprisingly, smoke with only moderate health effects was significantly more preferred (m = 1.35) than smoke that was unhealthy for sensitive groups (m = 0.88) or generally unhealthy for everyone (m = 0.40).

The most tolerable scenario, given the respondents and attributes of this study, was a lightning-caused fire in which the health effects were low, smoke did not last long in town, and residents received an advanced warning phone call notifying them to be aware of potential smoke and air quality concerns resulting from the fire.

Although the utility scores for levels of each attribute followed a similar pattern, regardless of how the data were grouped, a few interesting findings emerged related to previous experience with health effects from smoke, community preparedness for fire, and gender. Participants who had previously experienced adverse health effects from smoke from forest fire reported significantly lower smoke tolerance than participants who had not experienced adverse health effects from smoke from forest fire (Table 4). Previous adverse experiences with Rx fire have been shown to have persistent negative effects on perceptions of Rx fire. For example, following an escaped Rx fire in Utah, nearly half of the respondents in one study indicated that the fire had a negative impact on how they felt about Rx fire and increased their concerns about whether Rx fire would reach their property or special places (Brunson and Evans 2005). Other research related to fire and smoke has suggested that nearly one-third of US households consider smoke from forest fire to be a major issue because of health concerns and (or) the presence of household members with a health issue affected by smoke (Brunson and Evans 2005; Jacobson et al. 2001; Loomis et al. 2001; McCaffrey 2006; McCaffrey and Olsen 2012; Shindler and Toman 2003). However, the differences in our study were small (<15%), and even those who had experienced previous adverse health effects from smoke had a mean tolerance of smoke that was greater than zero for all but one condition.

Several studies have discussed the important relationships among space, community, and culture that define a WUI community and its level of preparedness for wildland fire (Bowker et al. 2008; Jakes et al. 1998, 2007; Paveglio et al. 2009). Shindler and Toman (2003) found that the more that people knew about mechanical thinning or Rx burning, the greater was the level of support for these practices. It seems logical that a community that is more prepared for wildland fire would be more aware of forest management objectives and the realities of smoke, leading to a greater tolerance of smoke than among residents in communities that are less prepared for fire and less aware of the role of fire in forest management. However, in our study, the differences were small and not statistically significant. We also observed no significant differences between urban and rural communities (Table 4). Our findings are consistent with a growing body of literature that suggests that many communities encompass a mosaic of varying interests and do not fit within traditional, presumably homogeneous categories (Racevskis and Lupi 2006), notably within the WUI (Paveglio et al. 2009).

Other research related to fire has found that women were more concerned than men about the potential adverse effects of Rx fire near their homes and, subsequently, less supportive of the use of Rx fire (Lim et al. 2009; Ryan and Wamsley 2008). However, the differences in utility scores for men and women were not statistically significant in our study, being less than 3% for all items.

Table 5. Relative importance values for each attribute by region, community type, gender, and prior experience with health effects from smoke.

Attribute	Total	non-WUI	WUIMP	WUILP	Urban	Rural	Men	Women	Health — Y	Health — N
NORO										
Fire origin	32	31	32	33	34	32	33	30	32	33
Advanced warning	27	28	26	26	26	27	26	27	27	25
Smoke duration	19	17	20	20	19	19	19	19	18	21
Health effects	22	24	22	21	21	23	22	23	23	21
Total	100	100	100	100	100	100	100	100	100	100
SOUTH										
Fire origin	28	—	—	—	—	27	27	—	—	27
Advanced warning	29	—	—	—	—	28	30	—	—	29
Smoke duration	19	—	—	—	—	19	19	—	—	19
Health effects	25	—	—	—	—	26	25	—	—	25
Total	100	100	100	100	100	100	100	100	100	100
TOTAL										
Fire origin	31	31	31	32	31	31	32	30	33	31
Advanced warning	27	28	27	26	27	27	27	27	25	28
Smoke duration	19	17	20	20	19	19	19	19	21	18
Health effects	23	24	22	22	23	23	22	23	21	23
Total	100	100	100	100	100	100	100	100	100	100

Note: Importance values are expressed as mean percentage. NORO, northern Rockies sample; SOUTH, south-central sample; TOTAL, combined regions; non-WUI, communities not located in the wildland–urban interface; WUIMP, WUI communities that were more prepared for fire; WUILP, WUI communities that were less prepared for fire; Health — Y, respondents that had previously had an adverse health impact from smoke; Health — Y, respondents that had not previously had an adverse health impact from smoke.

Relative importance of the attributes

In the NORO, the origin of the fire was consistently the most important factor (>30% of smoke tolerance), followed by advanced warning (25%–28%), health effects from smoke (21%–24%), and lastly the duration of the smoke in the community (17%–21%) (Table 5). In the SOUTH, advanced warning (29%) was slightly more important than the fire origin (28%), health effects from smoke (25%), and the duration of the smoke (19%).

Two surprises emerged from the relative importance findings: (*i*) advanced warning was consistently perceived to be more important than negative health effects and smoke duration, and (*ii*) there were somewhat similar relative importance percentages among the four attributes, regardless of data stratification (Table 5). Given previous research that has documented the importance of existing health conditions and concern for smoke (e.g., Brunson and Evans 2005; McCaffrey 2006; McCaffrey and Olsen 2012; Shindler and Toman 2003), we anticipated that health effects would be one of the more important attributes. The relative importance range of 21%–24% that we found for health effects does show that health effects are a prominent concern. However, the fact that advanced warning was consistently perceived to be more important than health effects could be associated with the fact that advanced warning allows people to prepare or evacuate before smoke is present, thereby mitigating or avoiding the potential adverse health effects. For example, a personal phone call to community residents who are known to have existing health conditions or a public service announcement would alert residents to the smoke threat and allow them to take precautionary measures within their residence (e.g., close doors and windows or use air purifiers), plan to limit outdoor activities during the anticipated smoke presence in their community, or evacuate the area until the smoke threat has subsided. The desire for personal interaction when receiving information about potential fire or smoke information is consistent with previous research that has shown less public preference for impersonal information sharing (McCaffrey and Olsen 2012; Toman et al. 2006).

The second surprise was that the relative importance values consistently ranged from approximately 20% to 35% importance, without a clear differentiation among the attributes. This is not consistent with most other conjoint studies that have involved rating full-profile scenarios. A 20-year review of conjoint studies found that it was common for participants to clearly focus on a small number of attributes, resulting in high importance values for those attributes, while the others had almost zero importance (Huber 1997). One explanation for our anomalous findings might be that our study participants were weighing the nine conjoint scenarios rather equally and were not strongly targeting particular smoke attributes. This could be because (*i*) the attribute levels were not clearly understood by participants (e.g., short duration of smoke (6 h) was not considered different from the long duration), or (*ii*) the public did not find the attributes of smoke, or smoke in general, to be a salient concern, or (*iii*) all attributes really are equally important. Previous research has suggested that for the general public, smoke may not be a major concern (Blanchard and Ryan 2007; Brunson and Shindler 2004; McCaffrey and Olsen 2012; Shindler and Toman 2003), and as we have noted, general tolerance was high among our respondents.

Contrasting the multivariate conjoint and univariate techniques

A separate survey question, apart from the conjoint analysis, asked participants to rate the relative importance of each of the four independent conjoint attributes by allocating 100 points across them (Table 6). This task prompted participants to consider each attribute individually, rather than indicating their tolerance of full scenarios (i.e., conjoint). Interestingly, in the univariate approach in both regions and across all stratifications, participants consistently identified health effects as the most important attribute (41%–53% of overall tolerance). In the NORO, the second most important attribute was smoke duration in the community (19%–23%), followed by the fire origin (16%–21%), and lastly advanced warning (12%–18%). In the SOUTH, advanced warning and duration were rated as the second most important attribute (15%–22%), with fire origin least important (13%–15%). Thus, there was a clear difference between this univariate approach and the multivariate conjoint approach, notably the reversed importance of health effects and smoke duration with fire origin and advanced warning.

Our findings about these methodological differences are consistent with some previous research from the health fields that have compared the two techniques and found that they produced different results (e.g., Ryan et al. 2001). In a comparison of multiple methods, Johnson et al. (2006) found that conjoint analysis allowed for a more accurate depiction of participant preferences. However, comparison of the two approaches is worthy of future

Table 6. Self-reported univariate importance of each smoke attribute by region, community type, gender, and prior experience with health effects from smoke.

Attribute	Total	non-WUI	WUIMP	WUILP	Urban	Rural	Men	Women	Health — Y	Health — N
NORO										
Fire origin	20	21	20	18	20	19	20	20	16	21
Advanced warning	16	18	15	15	16	17	16	16	12	17
Smoke duration	21	19	22	23	21	22	22	21	23	21
Health effects	43	41	43	44	43	41	43	44	49	41
Total	100	100	100	100	100	100	100	100	100	100
SOUTH										
Fire origin	14	14	13	15	13	15	14	15	11	14
Advanced warning	20	21	22	17	21	18	21	18	15	21
Smoke duration	19	19	19	19	19	19	19	19	21	19
Health effects	47	46	46	49	47	47	48	48	53	46
Total	100	100	100	100	100	100	100	100	100	100
TOTAL										
Fire origin	19	19	19	17	19	18	19	18	15	18
Advanced warning	17	19	16	15	16	17	16	16	12	18
Smoke duration	20	19	21	21	20	20	20	21	22	20
Health effects	45	43	44	47	45	45	45	45	51	44
Total	100	100	100	100	100	100	100	100	100	100

Note: Importance values are expressed as mean percentage. NORO, northern Rockies sample; SOUTH, south-central sample; TOTAL, combined regions; non-WUI, communities not located in the wildland–urban interface; WUIMP, WUI communities that were more prepared for fire; WUILP, WUI communities that were less prepared for fire; Health — Y, respondents that had previously had an adverse health impact from smoke; Health — N, respondents that had not previously had an adverse health impact from smoke.

study to examine whether differences widely exist between the univariate and multivariate conjoint approaches in natural resource settings or whether the findings are isolated to this study and topic. It is our opinion that these findings demonstrate to fire managers and policy makers the usefulness of conjoint analysis for potentially yielding a more accurate depiction of public preferences than a univariate approach, because it forces participants to make trade-offs between the variables in multiple scenarios rather than simply ranking variables one at a time. If, as in the case of smoke, desirable attributes cannot all be simultaneously maximized (e.g., short duration, minor health effects, and adequate advanced warning), conjoint results could be more valid.

Conclusions

Overall, our findings suggest that smoke from both wildland and Rx fire may not be a widespread concern, based on the high tolerance scores and minimal differentiation in the smoke attributes and scenarios. However, participants consistently reported that receiving advanced warning about the potential presence of smoke in their community was important. This is a topic worthy of further consideration because it is one aspect of Rx fires that managers can address in public outreach. Further, people preferred personal forms of communication such as a phone call rather than general public service announcements. Public communication plans about smoke are recommended as part of Rx fire management standard operating procedures, but they do not always occur and could be more widespread and timely. Efforts could encompass developing procedures for identifying and working with individuals and population segments that have existing health conditions or are sensitive to smoke prior to impacts. With today's sophisticated fire behavior and meteorological models, there may also be cases in which fire managers can provide advanced warnings for communities likely to experience smoke from lightning-ignited or management-ignited fires.

Research on other natural hazards such as hurricanes has highlighted the importance of understanding the public's preferences for early warning systems. Future research should focus on better understanding public preferences for advanced warnings related to the timing, magnitude, location, and health impacts of smoke (Gladwin et al. 2009; Joint Fire Science Program 2013). Modern society allows urban and rural community residents to receive information from multiple high-speed sources via the internet, cell phones, and television. In addition to understanding public preferences for content and modality of warnings, future research related to creating fire-adapted communities should evaluate existing and new information sources, community dissemination channels, and the structure, format, and timing of warnings.

As often occurs with general population surveys, a potential limitation of this study was the sample size obtained in the SOUTH. Specifically, the limited number of responses obtained in the SOUTH prevented conjoint analysis from being conducted on many of the data groupings for that population. Though we did run conjoint analysis on the “rural” and “men” groups from the SOUTH, some caution should be used when interpreting these results because the samples fell below the recommended number of 200 for conjoint analysis.

Another limitation relates to the type of conjoint analysis design that we used. Had we used a choice-based method rather than a rating method, we might have seen a larger spread between the utility scores and relative importance values. This would likely have been a result of the participants making a faster, simplified decision when comparing scenarios. It has been shown that asking respondents to compare multiple scenarios in a more complex design leads them to simplify the task by focusing more on the most important attribute(s), which can generate more differentiation among the attributes than we observed. Nevertheless, our intent was not to determine which attributes were most important in a rapid choice situation (e.g., purchasing toothpaste in a store); instead, we desired careful consideration of each attribute and scenario.

Another potential limitation of our approach was that it did not allow for the investigation of interaction effects between the attributes because to do so would have created a substantial burden for respondents. However, previous research has demonstrated that direct effects typically account for more than 80% of the variance in the dependent variable (Hair et al. 2010). Given that this was the first exploratory study using conjoint analysis in this context, we were satisfied with analyzing direct effects and confident in our full-profile rating approach.

The comparison between the conjoint and univariate rating exercises raised our attention to the possibility of a primacy effect (i.e., the order of information presented biases responses) in which a participant pays more attention to the information that was presented first than information presented later (Cohen et al. 2010). Future studies should consider randomizing the order in which the attributes are presented to account for a potential sequencing and primacy effect.

The goal of this study was to use a conjoint approach to deconstruct how context-specific factors and trade-offs affect public tolerance of smoke from forest fires. Comparing our multivariate conjoint approach with a univariate approach demonstrated that the two techniques can produce varying results, and that our conjoint approach was an effective tool for examining trade-offs and preferences related to public tolerance of smoke from forest fires.

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