

Examining Patterns of Air Quality Perception: A Cluster Analysis for Southern Chilean Cities

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Abstract

Various medium-sized cities in southern Chile are saturated by air pollution caused by woodsmoke. In this study, we developed a segmentation model to assess the public's perceptions, understanding of health risks and emotional responses to poor air quality. To date, this is the first segmentation model dealing with public perception in cities contaminated by woodsmoke. A survey ($N = 489$) was conducted in Temuco and Padre las Casas, Chile, which included questions regarding attitudes, sociodemographic factors, and health care behaviors, to obtain information for mitigation initiatives. Through a cluster analysis, three population segments were identified that related differently to environmental pollution, which were constructed based on seven psychosocial variables. Different sociodemographic profiles and self-reported behavioral patterns were found, which should guide policies aimed at improving air quality in cities contaminated by pollution from wood-burning stoves.

Keywords

air pollution, air quality perception, audience segmentation, social marketing

Introduction

One of the main environmental policy objectives in Chile, as in other Latin American countries (Catalán, Riojas, Jarillo, & Delgadillo, 2009; Cifuentes, Krupnick, O'Ryan, & Toman, 2005; Ramírez, Mura, & Franco, 2017), is the control of air pollution, particularly in this case, in medium-sized southern cities. Burning wood in technologically inefficient stoves generates large quantities of air pollution that results from incomplete combustion, including particles, carbon monoxide, nitrogen oxide, sulfur oxide, polyaromatics, hydrocarbons, and various organic substances (Naeher et al., 2007). In recent years, several studies in medium-sized southern Chilean cities have attempted to estimate the impact on health caused by daily exposure to poor outdoor and indoor air quality (Díaz-Robles et al., 2014; Jorquera et al., 2018; Sanhueza et al., 2009). Mortality and morbidity research has identified coarse particulate matter (PM10) and fine particulate matter (PM2.5) as the main causes of premature death and hospital admissions in those cities (Díaz-Robles, Cortés, Vergara-Fernández, & Ortega, 2015; Díaz-Robles et al., 2014; Díaz-Robles et al., 2008; Sanhueza et al., 2009; Schiappacasse, Díaz-Robles, Cereceda-Balic, & Schwartau, 2013).

Temuco and Padre las Casas were declared saturated zones by PM10 and PM2.5 in 2010 and 2013, respectively. Chilean regulation defines saturated zones as those where

one or more environmental quality standard has not been met for at least 3 years. A city's designation as a saturated zone is a prerequisite for qualifying for an atmospheric decontamination plan (ADP). In general, ADPs are normative instruments that regulate and promote the collaboration of different sectors in controlling pollution through programs and incentives. The goals of these programs are aimed at (a) the improvement of the stoves and appliances that heat homes, (b) fuel improvement, (c) thermal insulation of homes, and (d) educational campaigns. In 2015, the first PM2.5 ADP in the history of Chile was published, for both Temuco and Padre Las Casas, where it was estimated that the use of firewood was responsible for 94% emissions of said pollution. However, despite advances in recent years to improve air quality, air pollution from woodsmoke continues to be a difficult problem to solve. ADPs in Temuco and Padre las Casas have not achieved a substantial improvement in air quality

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during the winter period. In fact, according to the World Health Organization (2018), both communes are among the 20 cities with the worst air quality in Latin America. In response to this situation, health authorities have recently implemented restrictions on using wood stoves during critical periods. This initiative caused a lot of controversy, as approximately 80% of the population uses wood stoves to heat their homes or to cook. Many wood stove users belong to vulnerable households, for whom using other sources of energy, such as gas, pellets, paraffin, or electricity, would constitute an economic problem.¹

One of the greatest challenges in improving the air quality of cities saturated with woodsmoke is the development of effective policies to promote citizen involvement and changes in behavior (Boso, Hofflinger, Oltra, Alvarez, & Garrido, 2018; Boso, Oltra & Hofflinger, 2019; Reeve, Scott, Hine, & Bhullar, 2013). This is not an easy task, however, and several studies have exposed the limitations of environmental policies in making significant and stable behavioral changes within populations, often the result of not considering the heterogeneous nature of the target audience (Campbell & Corley, 2012; McKenzie-Mohr, 2011; Poortinga & Darnton, 2016). Often, universalist environmental policies tend to generate inefficient results. For example, restricting wood stove use could undoubtedly improve the air quality and, therefore, the quality of life of a population, but not all people react favorably. When interventions do not recognize the distinct circumstances of individuals, they typically react heterogeneously (Poortinga & Darnton, 2016), and often ignore recommendations completely (Bickerstaff & Walker, 2001). General information campaigns can help to raise awareness and change certain attitudes, but are rarely effective in modifying citizen behavior (Corner & Randall, 2011; McKenzie-Mohr, 2011).

In recent decades, segmentation or household studies have attempted to determine patterns of sustainable behavior (Poortinga & Darnton, 2016), especially in relation to energy consumption (Ben & Steemers, 2018; Sütterlin, Brunner, & Siegrist, 2011). The most widely recognized segmentation model was developed by the Department for Environment Food & Rural Affairs (2008), and denominated the framework for pro-environmental behaviors. Despite its limitations, the model has been widely used by scholars, policymakers, and other actors (Horton & Doran, 2011; Miller, Rathouse, Scarles, Holmes, & Tribe, 2010; Zimmermann et al., 2012). Segmentation has also been frequently utilized to improve the communication of risk in the field of perceptions and attitudes toward climate change (Hine et al., 2014; Hine et al., 2013). For instance, the *Global Warming's Six Americas Model* (Leiserowitz, Maibach, & Roser-Renouf, 2010; Leiserowitz, Maibach, Roser-Renouf, & Hmielowski, 2012; Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011) classifies the population into six segments according to beliefs, concerns, and motivation to fight climate change: alarmed, concerned, cautious, disengaged, doubtful, and dismissive. In recent years, domain-specific

segmentation models have also been developed to allow a better understanding of the motivation and perceived barriers for different audiences regarding specific environmental behaviors, such as recycling (Barr et al., 2013), energy conservation (Ben & Steemers, 2018), or urban transportation (Barr & Prillwitz, 2012). However, there are no studies that segment the population based on individuals' attitudes toward woodsmoke contamination.

Public Perception of Air Quality

Interventions aimed at promoting a reduction in air pollution from wood-burning stoves as well as to foster self-protective behaviors against air pollution among the general population require a thorough understanding of the public's perceptions, knowledge, and emotions regarding air quality and its risks. Individuals' perception of air quality is a key component in behavioral change and therefore plays a prominent role in the public's response to this environmental threat (Bickerstaff & Walker, 2001; Johnson, 2002; Oltra & Sala, 2016; Wu, Qi, Hu, Zhang, & Zhao, 2017), which has also been found in Latin American studies (Catalán et al., 2009; Ramírez et al., 2017).

Although several studies have already established a relationship between exposure levels to particulate matter produced by wood stoves and its respective health risks (Díaz-Robles et al., 2015; Díaz-Robles et al., 2014; Díaz-Robles et al., 2008; Sanhueza et al., 2009; Schiappacasse et al., 2013), few studies have focused on Chile's public perceptions of air quality and the associated risks (Álvarez & Boso, 2018; Boso et al. 2018; Vallejos-Romero & Oñate, 2013). Segmentation studies to categorize different sectors of the public are scarce in this domain, especially in the cities that are the most saturated by woodsmoke. This gap in the literature is a cause for concern considering the effectiveness of ADPs, which depend on perceptions regarding exposure to pollution, levels of concern, anger with the situation, and beliefs regarding potential health impacts. Psychological and sociological studies have revealed that public perception of air quality is influenced by several factors. Demographic, cultural, and certain contextual characteristics are crucial in understanding the variations in perception. Over the last decades, studies performed in different countries have shown that air quality perceptions can be associated with factors such as satisfaction and attachment with one's neighborhood (Bickerstaff & Walker, 2001; Brody, Peck, & Highfield, 2004; De Groot, 1967; Francis, 1983; Rankin, 1969), age (Brody et al., 2004; Howel, Moffatt, Prince, Bush, & Dunn, 2002), socioeconomic status, educational level (Bickerstaff & Walker, 2001; Deguen, Padilla, Padilla, & Kihal-Talantikite, 2017; Dworkin & Pijawka, 1982; Tiefenbacher & Hagelman, 1999), gender or feelings of belonging to a minority group (Catalán et al., 2009; Johnson, 2002), information and exposure to different types of risks and air quality (Chen et al., 2018; Elliott, Cole, Krueger, Voorberg, & Wakefield, 1999;

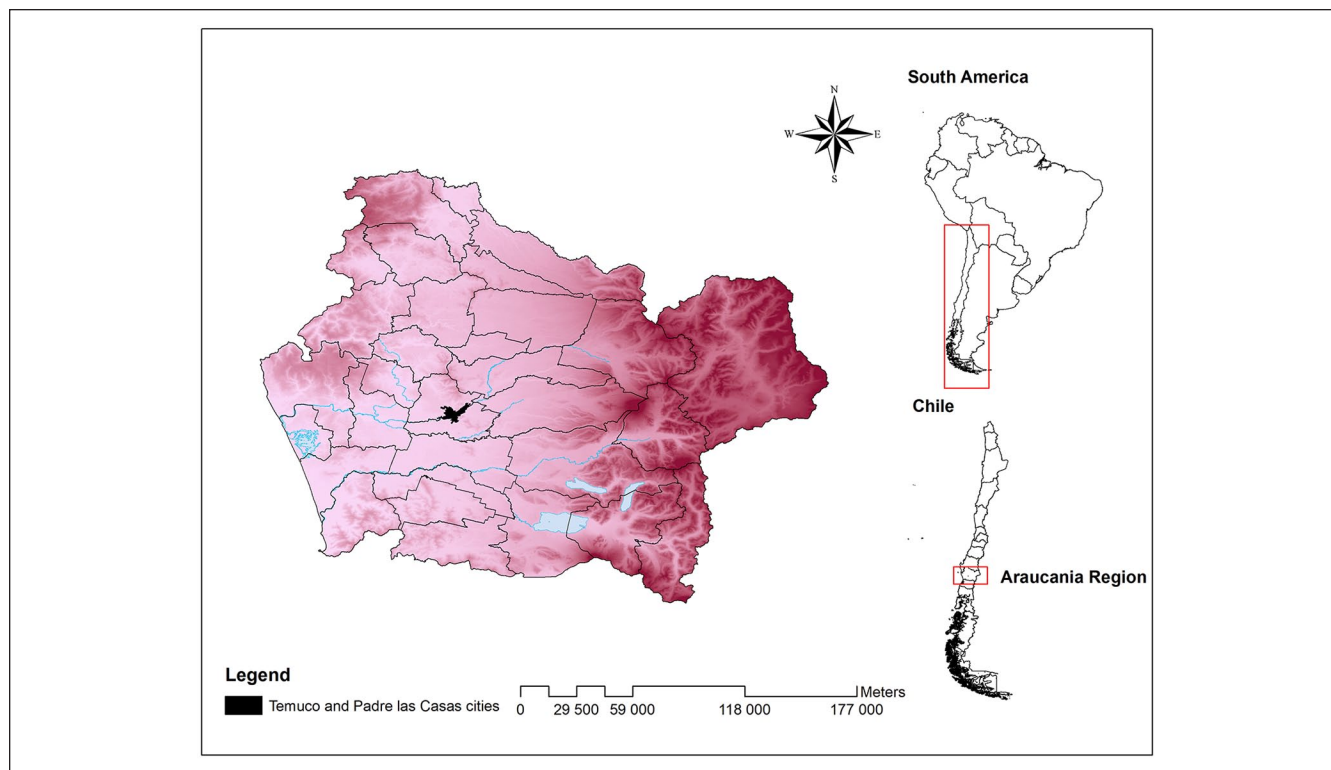


Figure 1. Studied areas location.

Kasperson et al., 1988; Mirabelli et al., 2018; Oltra, Sala, Boso, & Asensio, 2017; Saberian, Heyes, & Rivers, 2017), or political identification (Brody et al., 2004).

Although experts and public bodies recognize the effects of air pollution on public health, individuals do not always adequately understand these links (Chakraborty, Collins, Grineski, & Maldonado, 2017; Johnson, 2002). Therefore, perceptions of severity and susceptibility to the health effects of air pollution vary significantly across individuals and settings (Bickerstaff & Walker, 2001; Oltra & Sala, 2016). Studies have shown that although individuals sometimes recognize the severity of the health problems derived from air pollution, they tend to deny the potential impact on themselves (Bickerstaff & Walker, 2001; Reeve et al., 2013). This fact is particularly interesting in cities saturated with woodsmoke, where various psychosocial mechanisms explaining homeowners' decisions regarding residential heating systems have been studied (Boso, Ariztia & Fonseca, 2017; Hine, Marks, Nachreiner, Gifford, & Heath, 2007). Individuals may ignore the health risks of air pollution due to denial and resistance to changing their current heating system. This is largely due to immediate and personal concerns of wood users (e.g., economic considerations), as well as to the existence of certain beliefs and practices among wood users and linked to broader cultural, social, and identity factors in each community (Boso et al., 2017, 2019; Reeve et al., 2013).

To understand variations in public responses to air pollution due to the use of wood stoves, the present study develops a segmentation model for air quality perceptions based on attitudinal, sociodemographic, and self-reported behavior elicited through a survey. The ultimate objective of the study is to aid politicians in the design of communicative and behavioral interventions to control air pollution in cities contaminated by woodsmoke.

Method

Design and Sample

This study was cross-sectional and based on a household survey that was applied in two communes in southern Chile: Temuco and Padre las Casas (see Figure 1). Although the two communes are administered differently, they are placed side by side, being considered as a single city. In this sense, the study took the seven macro-sectors defined by the Communal Development Plan for Temuco and Padre las Casas as a basis of territorial differentiation. The macro-sectors have a certain social and functional homogeneity; thus, the number of participants was distributed equally.

The total sample population included 489 people, with ages from 18 to 89 years ($M = 43$, $SD = 18.6$). The sociodemographic characteristics of the participants are described in Table 1, through variables as sex, educational level,

Table 1. Sociodemographic Characteristics of Participants.

Variable	<i>n</i> (%)
Sex	
Male	191 (39.1)
Female	298 (60.9)
Educational level	
Primary	55 (11.3)
Secondary	138 (28.3)
University	274 (56.2)
Postgraduate	20 (4.2)
Indigenous	
Yes	78 (16.0)
No	411 (84.0)
Main heating system	
Wood stoves	268 (54.8)
Wood cooking stoves	70 (14.3)
Other wood-burning equipment	11 (3.2)
Alternative (pellet, gas, electricity)	135 (27.6)
Replacement program application	
Yes	105 (21.7)
No	384 (78.3)

indigenous identity, main heat source, and whether they had applied for the Seremi Environmental Program (Seremi de Medio Ambiente) to replace their firewood stoves with pellet stoves.

A nonprobabilistic convenience sample was used for data collection. We used random sampling criteria for households in the defined neighborhoods. The following was used as inclusion criteria for survey application: (a) houses that emitted visible smoke, and (b) houses that had applied to the wood stove exchange program.

Participants were contacted in their homes. Respondents had to be 18 years and above and be responsible for managing the heating system in their home (either individually or as a shared responsibility), in addition to voluntarily agreeing to participate in the study. Respondents were asked to sign a consent form.

Survey

The survey was composed of four sections: (a) demographic and socioeconomic information of the participants, such as age, income level, and education; (b) participant assessments of air quality and risks associated with air pollution; (c) participant habits regarding the use of firewood or other fuels for home heating; and (d) participant attitudes toward policies implemented in the city for the control of atmospheric contamination and the replacement of wood stoves for more environmentally friendly technologies.

The survey application was carried out in person and it did not involve any type of incentive for the participants. The average time to complete the survey was approximately 20 min.

Analysis

The data obtained were analyzed through the SPSS v21.0 program. Variables were analyzed using normal, atypical, univariate, and multivariate tests, according to Mahalanobis distance measurements (Tabachnick & Fidell, 2007). The Kolmogorov–Smirnov test revealed that none of the variables complied with the univariate normality assumption ($p < .001$), which is why we used nonparametric tests.

Regarding the cluster analysis, we used the Hopkins statistic's value to calculate the clustering tendency of the dataset, which help us to know whether there is a predisposition to cluster into natural groups without identifying the groups themselves (Adolfsson, Ackerman, & Brownstein, 2019). The resulting Hopkins value was .635, which is acceptable to conduct a cluster analysis ($H > .5$). Thus, a hierarchical cluster analysis was performed using Ward's method and squared Euclidean distance. We considered the following variables: (a) subjective evaluation of the air quality in Temuco, (b) subjective evaluation of the air quality in the neighborhood of residence, (c) subjective evaluation of the air quality in the work transit area, (d) distress caused by pollution, (e) anger caused by pollution, (f) displeasure produced by pollution, (g) perceived severity, and (h) concern regarding the health effects of air pollution. All variables were measured on a Likert-type scale, with scores from 1 to 5.

Descriptive statistics were estimated for each cluster for the variables used in conjunction with the nonparametric Kruskal–Wallis tests to reveal significant differences between the defined groups. Furthermore, the Mann–Whitney *U* test was used post hoc as a nonparametric alternative to compare each group pairing, and a Bonferroni

Table 2. Composition, Centroids, and Labeling of Each Cluster.

Variables	C1 (n = 226)		C2 (n = 151)		C3 (n = 96)		F	Post hoc ^a
	M	SD	M	SD	M	SD		
Perceived air quality (city)	1.85	0.79	1.48	0.60	2.69	0.73	81.384***	2 < 1 < 3
Perceived air quality (neighborhood)	2.16	0.90	1.71	0.68	2.89	0.78	60.990***	2 < 1 < 3
Perceived air quality (work)	2.33	0.85	1.83	0.70	3.05	0.73	71.226***	2 < 1 < 3
Anguish	3.52	1.08	2.60	1.01	1.59	0.87	124.585***	2 < 1 < 3
Anger	4.00	0.94	2.24	0.90	1.57	0.76	314.382***	2 < 1 < 3
Discomfort	4.56	0.63	4.17	0.87	2.66	1.02	189.298***	2 < 1 < 3
Perceived risk	4.67	0.55	4.19	0.94	3.46	1.16	70.728***	2 < 1 < 3
Concern about the effects of air pollution	4.27	0.81	3.83	0.88	2.92	1.17	73.558***	2 < 1 < 3
Label	Aware		Resigned		Accustomed			

^aThe signs < indicate the direction of significant relationships between conglomerates.

* $p < .05$. ** $p < .01$. *** $p < .001$.

adjustment was performed to increase the significance requirement level (Dinno, 2015). We then described and compared each cluster based on sociodemographic variables, self-reported health care behaviors, and involvement in controlling air pollution. This was completed by using nonparametric comparative tests (Mann–Whitney U test, Kruskal–Wallis test, and chi-square test) with residual analysis to detect significant differences.

Cluster Selection

Based on the indicators of conglomeration history and the dendrogram obtained from the hierarchical cluster analysis, it was determined that categorizing into three distinct groups was the most appropriate way to classify the population. To corroborate this information, a k -means nonhierarchical clustering analysis was executed to review the consistency of the first solution when comparing it with a different alternative. Both analyses showed a good level of consistency with respect to the profiles and group sizes, thus supporting our decision.

In addition, a discriminant analysis was completed to confirm that the selected variables allowed an adequate distinction between groups. It was estimated that the overall value of correctly classified cases in the clusters was 86.5% (C1 = 91.2%, C2 = 78.8%, C3 = 87.5%). On the contrary, using the leave-one-out cross-validation procedure, we observed that the eight variables considered had an 85.6% probability of correctly classifying future cases (C1 = 91.2%, C2 = 76.8%, C3 = 86.5%). This percentage of correct classification is high, achieved by simple random sampling among the three clusters (equivalent to 33%); it can therefore be said that discriminant analysis has a high level of prediction.

A multivariate analysis of variance (MANOVA) was performed with Tukey's post hoc comparisons to describe the selected clusters, identifying significant differences between

groups. Significant differences were found in all groups across all variables ($p < .001$). Means and standard deviations of each group can be seen in Table 2.

Results

Figure 2 presents the distribution of all cases from canonical functions by means of a scatter plot. This information provides evidence that the selected variables effectively separated individuals into three groups: (a) *aware*, (b) *resigned*, and (c) *accustomed*. Individuals in the first cluster, the *aware* group, evaluates negatively air quality in the city of Temuco, their neighborhood, and work area, and manifested higher feelings of anguish, anger, and displeasure regarding pollution. In addition, this group considers air pollution to be highly dangerous for their health and is concerned about the potential negative health impacts of air pollution. The second cluster, the *resigned* group, evaluates air quality as poor, but reports fewer feelings of anguish and anger than the previous cluster. Participants in this group report high levels of discomfort due to air pollution, but have a lower risk perception as compared with the other groups. Finally, the third cluster, the *accustomed* group, reports a more positive perception of air quality as well as less negative feelings regarding the health risks and the negative effects of pollution.

Table 3 shows that the clusters differ significantly in terms of sex, age, and wood stove use. In this sense, the *accustomed* group is mostly made up of women who live with people older than 60 years and make more use of wood stoves. The *aware* group has an average age of 42 years old ($SD = 17$), the *resigned* group 41 ($SD = 18$), and the *accustomed* group 49 ($SD = 20$; $p < .05$). On the contrary, no significant differences were found between groups regarding ethnic origin, education, or income level ($p > .05$).

Regarding self-protective behaviors, we observe that the groups perceive the health effects of air pollution at different

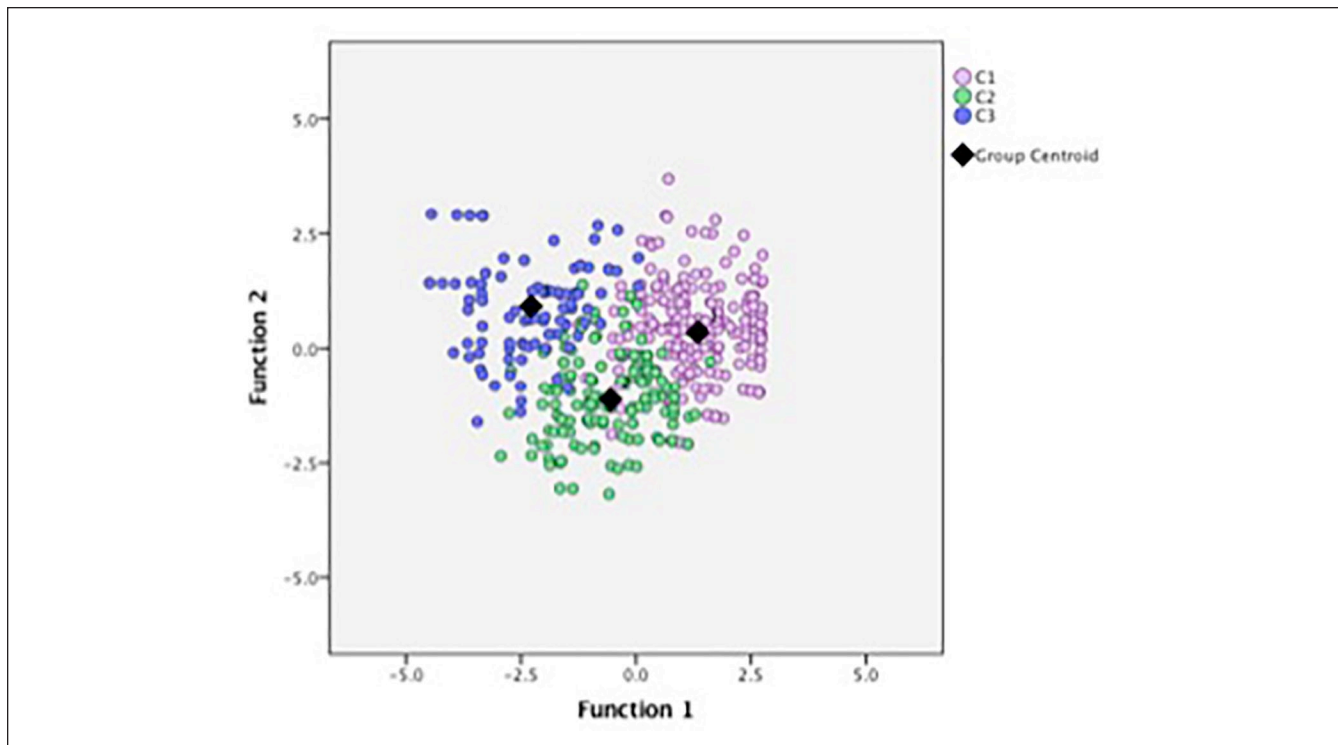


Figure 2. Canonical discriminant functions of participant cluster members.

Table 3. Sociodemographic Differences by Cluster.

Variables	Values	Clusters			χ^2
		Aware	Resigned	Accustomed	
Sex (female)	Male	77 (34.1%)	57 (37.7%)	50 (52.6%)	9.829**
Persons > 60	Yes	64 (28.3%)	45 (29.8%)	45 (46.9%)	11.334**
Wood stove use	Yes	150 (66.4%)	115 (76.2%)	76 (79.2%)	7.305*

* $p < .05$. ** $p < .01$. *** $p < .001$.

levels of severity ($p < .001$). Almost 77% of the individuals classified in the aware group believe that the health effects of air pollution are serious, as compared with only 64% in the resigned group and 32% in the accustomed group. The *accustomed* group presents the highest percentage of people who think that these effects are minor (20%); this figure is much lower in the *resigned* group (5%) and the *aware* group (2.2%).

When respondents are asked about the extent to which they have modified their behavior due to air pollution in the last month, we find statistically significant differences between the three segments (see Table 4). The *aware* and *resigned* groups report the largest changes in behavior due to air pollution. These groups prefer to stay at home, modify their usual leisure activities, avoid outdoor exercise, avoid opening windows, wear masks, or have even thought of moving, in a greater proportion than the *accustomed* group.

Table 5 shows respondents' level of involvement in the control of air pollution. Results show statistically significant differences between groups. The *aware* group reports performing more habitual activities such as talking to friends, looking for information regarding air pollution, and reading or listening to news. In comparison with the other two groups, participants in the *aware* cluster are more in favor of applying fines to households that emit smoke during restriction periods. The *resigned* group reports involvement behaviors at a lower percentage than the *aware* group and a greater percentage than the *accustomed*. Finally, the *accustomed* group has the lowest percentages in all the aforementioned behaviors except for complaining to authorities, in which the *resigned* group presents the lowest value.

Other behaviors that we considered that did not show significant differences between groups were the use of certified

Table 4. Protective Behaviors Against Pollution by Cluster.

Variables	Clusters			χ^2	Post hoc ^a
	Aware	Resigned	Accustomed		
Change leisure activities	2.61	2.30	1.71	47.984***	3<2<1
Avoid exercising outdoors	2.95	2.53	1.95	44.348***	3<1,2
Stay at home	2.96	3.06	2.59	9.252***	3<1,2
Avoid opening windows	3.04	2.79	2.22	31.913***	3<1,2
Use face masks	1.27	1.21	1.03	10.269***	3<1,2
Think about moving	1.51	1.54	1.13	16.290***	3<1,2

^aThe signs < indicate the direction of significant relationships between clusters.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 5. Involvement Behaviors for Atmospheric Pollution Control.

Variables	Clusters			χ^2
	Aware	Resigned	Accustomed	
Talk to friends	180 (80.4%)	96 (64.0%)	43 (44.8%)	40.496**
Search for information	99 (44.2%)	60 (40.0%)	24 (25.0%)	10.520**
Hear/read news	211 (49.9%)	135 (31.9%)	77 (18.2%)	10.498**
In favor of fines	140 (63.9%)	89 (59.3%)	44 (46.3%)	8.508*
Complain to authorities	16 (7.1%)	2 (1.3%)	2 (2.1%)	8.783*

* $p < .05$. ** $p < .01$. *** $p < .001$.

firewood ($p > .05$), and the replacement of firewood stoves with pellet stoves ($p > .05$).

Discussion

To explore the heterogeneity in public reactions to air pollution from wood stoves, a cluster analysis was used to construct three segments based on individuals' perceptions and emotions regarding air pollution as elicited through the survey. We determined the sociodemographic profiles of the different groups in terms of gender, age, level of education, income level, belonging to indigenous groups, and type of heating in the home. Finally, the segmentation model was validated with a series of measures of self-reported behaviors regarding urban air pollution. The ultimate goal of the study was to provide evidence to future political interventions on how to aggregate citizens into segments that have common needs and respond similarly to air pollution.

Our analysis identified three distinct clusters: (a) *aware*, (b) *resigned*, and (c) *accustomed*. Each segment displayed distinct perceptions and reactions to air pollution caused by woodsmoke as well as distinct behavioral patterns in response to air pollution. The *aware* group negatively evaluated the air quality of Temuco or Padre las Casas, as well as at their place

of residence and work. Emotionally, they felt angry and anguished by the situation and had concerns regarding the health risks generated by air pollution. The *resigned* group similarly perceived air quality as poor and were aware of the health risks generated by woodsmoke; however, they did not react with such anguish or anger. Finally, the *accustomed* group reported a more positive subjective evaluation of air quality than the other groups. Individuals in this group were the least concerned about the consequences of air pollution on people's health. We also found that older women living in households with wood stoves were overrepresented in this group. Due to their lack of protective behavior, they are the most vulnerable group, as well as the least involved in actions to inform themselves and mitigate pollution.

The model of segmentation yields results consistent with previous research. Age and gender appear to be two relevant factors in perception of air pollution and its associated risks (Dons et al., 2018; Howel, Moffatt, Bush, Dunn, & Prince, 2003; Johnson, 2002; Oltra & Sala, 2016). In a study performed in different European cities, Dons et al. (2018) found that men showed higher levels of concern about the problem of air pollution. In the same sense, the results of the presented model show that men are overrepresented in the *aware* group, while women are overrepresented in the

accustomed group. However, other studies have shown that women report higher levels of discomfort, although it is not clear what mechanism underlies that data (Jacquemin et al., 2007; Johnson, 2002).

One possible explanation for the different role played by sociodemographic variables in perception studies is that the psychosocial variables, as well as the behaviors derived from them, are strongly influenced by regional context and everyday experiences. Previous research has found important differences between cities (and even neighborhoods) in subjective evaluation measures (Brody et al., 2004; Simone, Eyles, Newbold, Kitchen, & Williams, 2012; Williams & Bird, 2003) regarding the nuisance generated by poor air quality (Jacquemin et al., 2007) or protective behaviors (Oltra & Sala, 2016). The differences found in the sociodemographic profiles of the groups invite us to imagine that in a certain sense, the perceptions and attitudes toward air pollution may correspond to different circumstances and life cycles throughout individual's lives. For instance, the strong traditional attachment to wood stoves and ovens in southern Chile, two multifunctional devices linked to different social customs and practices (Alvarez & Boso, 2018; Boso, Ariztia, & Fonseca, 2017), might explain the greater presence of older women in the *accustomed* group. Therefore, as suggested by several authors in previous studies (Anable et al., 2015; Poortinga & Darnton, 2016), it should not be assumed that the three segments have fixed preferences, as people's motivations and circumstances vary over time. It is not convenient to label the segments according to their predominant sociodemographic characteristics, as there are other variables that influence the formation of the groups. However, in line with studies based on the community-based social marketing (CBSM), the attitudinal segments that result from the study may help to identify factors underlying the decision to perform or not perform certain types of behavior (Corner & Randall, 2011; Lee & Kotler, 2011; McKenzie-Mohr, 2011). In this sense, the model provides information for air quality policies on how different segments of the public in southern Chile might perceive and react to the problem of woodsmoke pollution.

The association between the attitudinal variables defining the groups and the self-reported protective behaviors has two clear implications. First, to promote citizen participation in energy transitions, it is necessary to strengthen citizens' knowledge regarding air quality, its relationship to woodsmoke, and its potential health effects; this implication is consistent with previous studies (Oltra & Sala, 2016; Oltra et al., 2017). Second, the heterogeneity in public reactions to air pollution from wood stoves indicates the need for a higher specificity of any intervention aimed at modifying individuals' beliefs and behaviors. For instance, there is a certain segment of the public in which traditional social practices related to the use of ovens and wood stoves play a significant role in their daily life. This should be taken into account in any communication strategy. There is also a need to consider that the

public's emotional response to air pollution is diverse. Two segments of the population identified in the study, the *resigned* and *accustomed* groups, report low levels of concern and anger regarding air pollution as well as a lower involvement in the control of air pollution and the reduction of personal exposure. All this should be taken into account in the design of future interventions.

The study has several limitations. Cluster analysis is an exploratory statistical technique designed to examine attitudinal and behavioral patterns to segment the general public. In this sense, cluster models often discover patterns without providing explanatory mechanisms. Thus, like other segmentation studies, the model presented is, to some degree, atheoretical. However, despite recognizing this limitation, we believe that it is not a major hindrance. The selected factors are consistent with previous research and have been shown to be useful for predicting self-reported behaviors of protection and contamination mitigation. The aim of the study was to develop a comprehensive segmentation model that can be applied to design more tailored communications and behavior change initiatives in places where firewood is the main fuel used for heating or cooking. The observation that the three segments can be ordered along qualitatively distinct attitudinal dimensions and behaviors suggests the model is fit for that purpose. However, it is also important to point out that this study did not identify the behavior behind wood combustion, which could be used for heating, cooking, or drying clothes. This might be important to understand the global use perception and especially in terms of health risks. Regardless, as Jorquera et al. (2018) state, indoor and outdoor pollution in Chile is nearly the same, as 68% of the indoor pollution comes from outdoor infiltrations through windows, doors, ceiling, or cracks on the walls. This is considered reasonable to expect that if somebody is using wood combustion for heating or cooking, they will be exposed to similar health risks.

Finally, the sample was not selected in a completely random manner, which may have introduced some bias in the results. The selection criteria used and the relative breadth of the sample led us to assume that the estimates produced are sufficiently precise. Nevertheless, it cannot be assumed that the results of this study will generalize to Temuco and Padre las Casas as a whole, or to other communities that experience woodsmoke pollution. Additional studies will be required to establish the external validity of our findings.

Conclusion

The current study provides preliminary evidence for the existence of three distinct segments in the population of southern cities in Chile (aware, resigned, and accustomed) based on their perceptions and behavioral patterns regarding air pollution caused by woodsmoke.

From a practical perspective, this evidence suggests that educational interventions aimed at providing people with

information about the health risks associated with woodsmoke cannot be applied uniformly. The categorization of profiles into a risk perception typology for woodsmoke-polluted cities documents the systematic variability among participants with respect to their existing understanding of the problem and their behavioral responses. The differentiation of household types is vital for the local government responsible for managing local air quality, because it allows policy interventions to be geared toward identifiable groups of residents to maximize the impact and effectiveness. For instance, our findings indicate that issuing the same air quality alerts to the whole population could have a limited effect on encouraging protective health behaviors, given the existence of two segments that are either resigned or accustomed to a situation of severe pollution. The study also reveals that the involvement in local energy transitions of people, whose daily practices pivot around wood-burning stoves, can entail significant strains. Finally, although our results seem to be pertinent to many cities with severe air pollution levels, the external validity of the findings merits further investigation.

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Note

1. According to the latest survey of National Socioeconomic Characterization (Casen, 2015), the Araucanía region of Chile (of which Temuco is the capital city) is the area of the country with the highest rate of poverty by income (23.6% in the region, doubling the national average of 11.7%). This situation is not conjunctural, but reveals historical patterns passed within the region with high rates of rurality and indigenous populations (19% of the population, compared with 9% of the national average).

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