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Risk perception and coping strategies for risk from Popocatépetl Volcano, Mexico

E. López-Vázquez
Departamento de Psicología, Universidad Autónoma de Morelos, Cuernavaca, Morelos, Mexico

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Resumen

El objetivo de este estudio es explorar la percepción de riesgo y las estrategias de afrontamiento utilizadas por personas adultas que viven cerca del volcán Popocatépetl en México. Se recolectaron datos tanto cualitativos como semi-cuantitativos a partir de un cuestionario que se aplicó a las 192 personas participantes. Éstos, fueron divididos en cuatro grupos (G1-G4) conforme a la zona de riesgo en la cual viven (en general el grado de peligro volcánico disminuye con la distancia). Sin sorpresa, observamos que el riesgo volcánico fue percibido como más preocupante por la gente que vive en la zona más cercana al cráter del volcán. Sin embargo, cuando preguntamos sobre los riesgos que los afectán más directamente, estas percepciones cambian, y el riesgo volcánico es evaluado como el riesgo más importante para los grupos G1, G2 y G3. A pesar de la información dada por las autoridades de Protección Civil, un alto porcentaje de personas expuestas a los peligros volcánicos no se sienten preparadas para enfrentar un evento eruptivo y no tienen estrategias para enfrentar los riesgos percibidos. Un alto porcentaje de participantes en los cuatro grupos sostuvieron que ellos dejarían la zona si ocurriera una erupción. Esta afirmación refleja una seria falta de información, puesto que las autoridades civiles no sugieren que la gente que vive en las zonas tres y cuatro evacuen. Se sugiere reforzar las campañas de información pública en las comunidades cercanas al Popocatépetl.

Palabras clave: Percepción de riesgos, peligros del medio ambiente, riesgo volcánico, estrategias de afrontamiento, volcán Popocatépetl.

Abstract

The goal of this study is to explore risk perception and coping strategies used by adults living near the volcano Popocatépetl in Mexico. Qualitative and semi-quantitative data were collected with a questionnaire from 192 adult respondents. These respondents were divided into four groups (G1-G4) according to the risk zone in which they live (generally the degree of hazard decreases with increasing distances from the volcano). Analyses of the completed questionnaires were made according to sex and age range of the respondents. Not surprisingly volcanic risk was perceived as more worrisome by people living in the zone nearest the volcano's crater (G1). However, when we asked what risks could affect them directly, perceptions changed, and volcanic risk was appraised as the most important risk potentially affecting them and their homes for risk zones G1, G2 and G3. Despite sporadic information given by the Civil Defense authorities, a high percentage of people exposed to volcanic hazards do not feel prepared to face an eruptive event, and people have no strategy to cope with general perceived risks. A high percentage of participants in the four groups stated that they would leave the area if an eruptive event occurred. This statement reflects the serious misinformation, because civil authorities do not require people living in the third and fourth zones to evacuate. The results of study demonstrate the critical need to reinforce public information campaigns regarding volcanic risk in communities vulnerable to direct damage in the event of a stronger eruption of the volcano Popocatépetl.

Key words: Risk perception, environmental risks, volcanic risks, coping strategies, Popocatépetl.

Introduction

Some estimation of eruptions around the world indicates that on average 50 to 60 volcanoes erupt per year (Simkin, 1988). In Mexico, there are 16 active volcanoes, six of which are considered high risk, seven are of medium risk, and three are of moderate risk according to the number of people living around them (De la Cruz and Ramos, 1992). Those posing high risk include the volcano Citlaltépetl in Veracruz, Chichonal and Tacaná in Chiapas, Colima volcano in Colima and Jalisco, and the volcano Popocatépetl, which covers parts of the States of Mexico, Puebla and Morelos (Fig. 1A). Many of these active volcanoes are located in the Trans-Mexican volcanic belt that traverses central Mexico (Mansilla, 1993). Popocatépetl, whose crater is located 60 km from Mexico City, 40 km from Puebla, and 15 km from the nearest village, is one of the most active volcanoes in Mexico, with intermittent periods of activity (Fig. 1B). Its Holocene volcanic history consists of large Plinian eruptions that have affected large areas around the volcano (Siebe *et al*., 1996). In 1920, Popocatépetl had an active period that lasted 7 years, consisting of several explosive events that produced eruptive columns, but no pyroclastic flows. Then it went dormant for about 70 years. On December 21st, 1994, Popocatépetl reawakened with intense seismic activity that consisted of explosions which generated a 7 km-high ash column that produced a fallout that reached 50 km to the north and east. On December 24-25 (1994), the strongest eruptive phase of the volcano

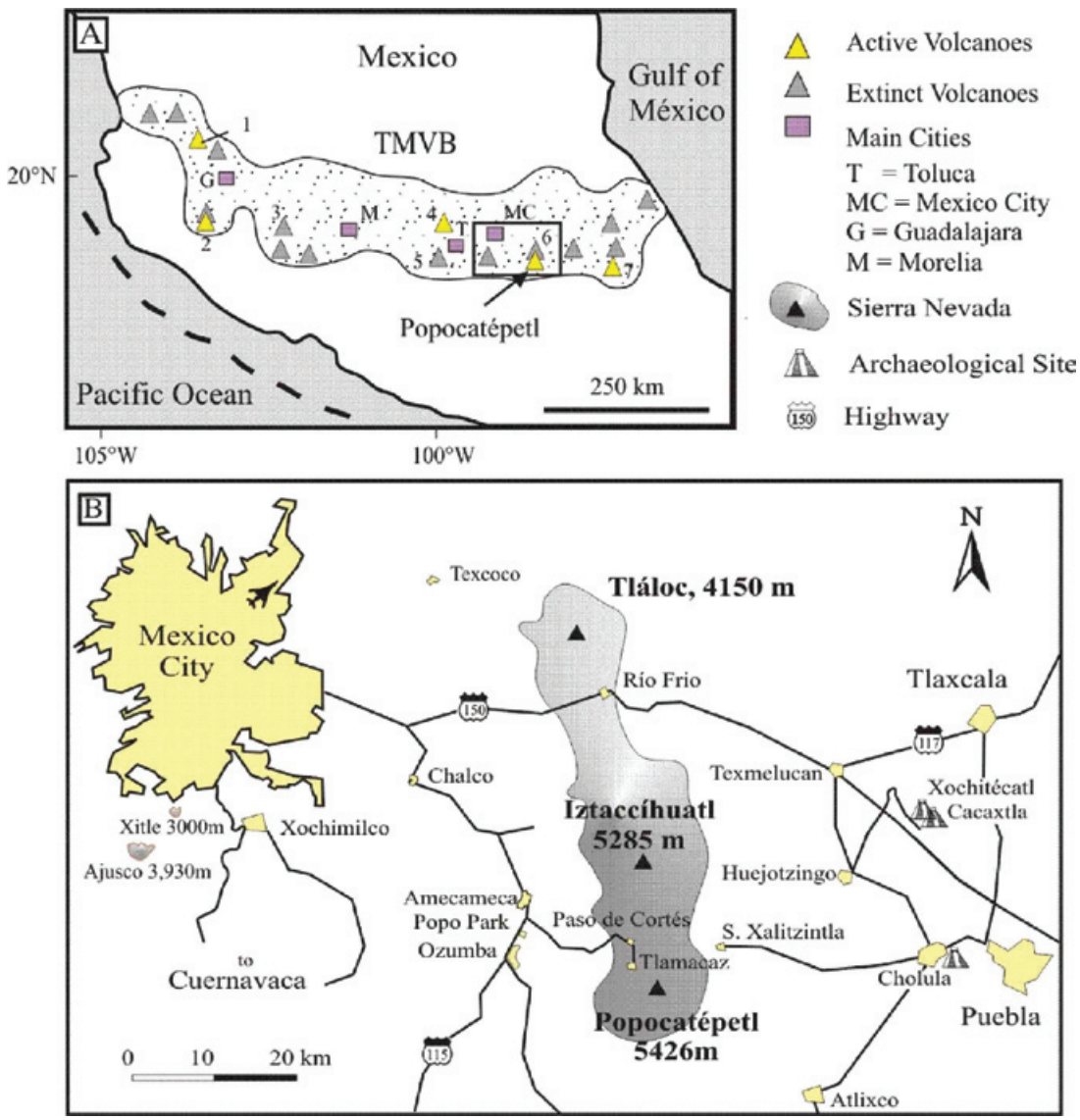

Fig. 1. A. Location of Popocatépetl volcano within the Trans-Mexican Volcanic Belt. Volcanoes are: 1) Ceboruco, 2) Colima, 3) Parícutin, 4) Jocotitlán, 5) Nevado de Toluca, 6) Iztaccíhuatl, and 7) Citlaltépetl. B. The inset shows the cities of Mexico and Puebla and main towns surrounding Popocatépetl volcano.

occurred after a brief eruptive activity decline. Since then, the activity of the volcano has been intermittent and fluctuant. This situation prompted scientists to elaborate a volcanic hazard map for pyroclastic flows, tephra falls, landslides, and lahars (Macías *et al*., 1995). This map shows a hazard zoning for pyroclastic flows and lahars into three main zones located at circa 15, 20, and 25 km from the volcano summit. In addition, it shows three hazard zones for pyroclastic falls located at 15, 25, and 80 km from the crater. In this study, we considered the three hazard zones for pyroclastic flows of Macías *et al*. (1995), and a fourth farthest zone located between 25 and 80 km from the summit that corresponds to the yellow hazard zone for tephra falls of the same authors (see simplified Fig. 2).

The first hazard zone includes pyroclastic flows, lahars, and ash fall. Possible hazards in the second and third zones are the same as those in the first, but eruptions that have affected the second and third zones have been less frequent than in the first zone. Finally, the fourth zone could be affected by ash fall, but at a lower intensity than that for the other zones closer to the volcano (Macías *et al*., 1995; Macías y Capra-Pedol, 2005; De la Cruz and Ramos, 1995). Ash falls can be very dangerous. In the case of a violent eruption, ash falls can travel long distances, as occurred in the Krakatoa volcano eruption of 1883, the Chichonal eruption of 1982, and the Pinatubo eruption of 1991. These examples have caused atmospheric and climate changes (De la Cruz and Ramos, 1995). The accumulation of heavy ash on rooftops may lead to their collapse, and also can be dangerous for health if inhaled, drank or eaten in polluted water or food during ash fall, wearing a protective mask is suggested. It is recommended that animals be moved to a safe place, since being exposed to the ash or contaminated food or water could kill them. In the case of the Chichonal eruption, the ash fall produced damage to the crops, total interruption of air traffic and partial disruption of ground traffic in the neighboring states of Chiapas, Tabasco, Campeche, and some parts of Oaxaca, Veracruz and Puebla (De la Cruz and Ramos, 1995). This eruption killed at least 2000 people, destroyed 9 villages, caused important global effects to the atmosphere, and reduced surface temperature during some months (Macías, 2005).

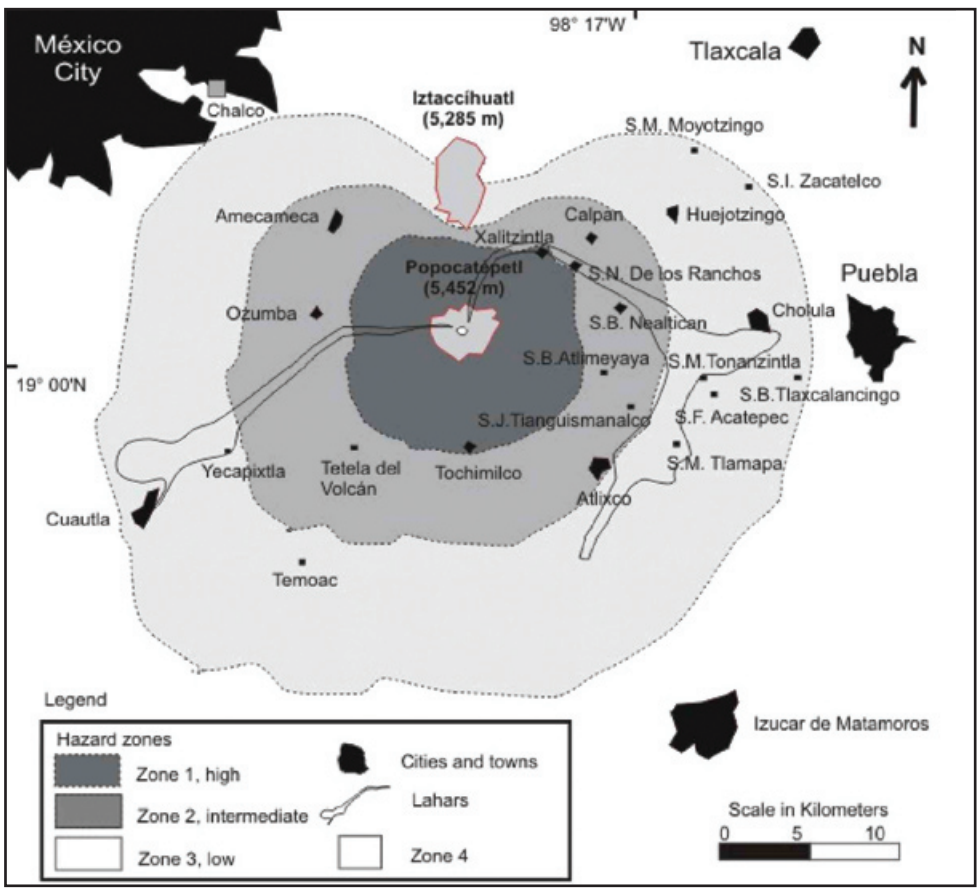

Fig. 2. Location of the study sites regarding the pyroclastic-flow-related hazard zones of Popocatépetl volcano simplified from Macías *et al*. (1995). This simplified figure shows the extent of the three hazard zones for pyroclastic flows and lahars of Macías *et al*. (1995) and a four zone that corresponds to the yellow-hazard zone of tephra fall of these authors that practically covers the whole area of the fig.

People exposed to all kinds of volcanic hazards are confronted with uncertainty, and usually, living with risks becomes a daily condition to which they adapt. Adaptation to threatening environments is determined by the personal resources that people have. These resources allow them to protect their own physical and psychological stability. All actions used to confront a stressing event are called coping strategies (Lazarus, 1991). Coping can include active ways of solving problems such as seeking information and social support, direct actions to control the situation, and methods for managing stress that include all actions to control emotional overflowing (Murphy and Moriarty, 1976; Lazarus and Folkman, 1984). People's resources are frequently underestimated, but most of the time people are able to cope with stressing events successfully.

Another important variable to take into account when studying people exposed to hazards is the perception of risk. Different aspects of this variable have been studied in recent decades in many theoretical aspects of the fields of psychology and social psychology. Some of the most common approaches to studying risk perception are:

a) In considering objective versus subjective perception of risk, it is important to understand the heuristics and cognitive biases influencing people's risk perception, and the mental modeling of their cognitive representations of risk. A brief explanation about these terms: 1) *heuristics* is a cognitive method used to resolve problems or determine rules of action by applying specific principles to a wide range of problems. The specific characteristic of heuristics is that it represents estimations or associations of ideas which are readily acceptable to the mind of the subject but which have no basis in reality; 2) and *cognitive biases* are systematic deviations with respect to a norm; this implies judgments that have a certain rationality but that do not correspond to any real logic (Fischhoff *et al*., 2000a; Slovic, *et al*., 2000).

b) The psychometric paradigm which focuses on expressed preferences of people and associated factors, rather than preferences revealed through behavior. This method looks to create a taxonomy of hazards, to help us understand and predict what people will answer regarding certain hazards. This approach uses psychophysical scaling, (questions related to the psychological and physical states to which the individual responds by expressing degrees of affinity, i.e. agree or disagree. (These questions, acording to Kerlinger & Lee (2001), place the participant along the scale) and multivariate analysis techniques to produce quantitative representations or "*cognitive* maps" concerning risk attitudes and perceptions (Slovic *et al*., 2000; Fischhoff *et al*., 2000a, Fischhoff *et al*., 2000b; Slovic 2000).

c) The social amplification of risk framework that analyzes the psychological, institutional and cultural mechanisms and processes that allows the amplification or attenuation of public responses to the hazard (Kasperson, *et al*., 2005).

d) Cultural approaches, where the importance of the cultural influence in perception and behavior towards the risks and hazards in the population is analyzed (Douglas and Wildavsky, 1982).

e) Risk perception is influenced by social trust which includes on one hand, the competence and responsibility of the regulating organisms and, on the other, the social and cultural values that influence the level of trust that people have towards said organisms (Siegrist, 2000; Siegrist and Cvetkovich, 2000; Siegrist *et al*., 2000; Siegrist, *et al*., 2003; Cvetkovich & Löfstedt, 1999).

f) Emotions involved in the perception of a hazard (Lerner and Kelter, 2000, Lerner *et al*., 2001; Lerner *et al*., 2003; Slovic, 2004; Slovic *et al*., 2004)

g) The effect of risk perception in mental health that concerns studies on stress and coping strategies (López-Vázquez, 2001; López-Vázquez and Marván, 2003; Lange *et al*., 2004).

Collectively, these approaches to risk perception highlight the complexity of an important subject that involves different disciplines. However, a number of issues are still unresolved. Problems of risk perception have resulted in multiple social concerns and one of these is the population's poor level of preparation for volcanic eruptions.

Taking into account the complexity in confronting risks, we explored in our study: a) the preoccupation that people feel for different types of risk, b) the perceived risks when subjects feel it necessary to reinforce preventive measures, c) the priority that people give to volcanic risk, d) the level of preparedness that the people exposed to the risks of the Popocatépetl feel they have, and e) the coping strategies that people use to deal with volcanic risks.

The objective of this study is to explore the risk perception, and the coping strategies of people exposed to volcanic risk, and to compare the differences considering the risk zone in which each group of people lives. Furthermore, differences by gender and age were taken into account. We expected that volcanic risk would be perceived as more worrisome in the two groups living in the hazard zones closest to Popocatépetl's crater, and that this risk would be displaced in importance by other

risks in the two groups belonging to the more distant hazard zones. We also compare, within the four groups, perceived risks, coping strategies and the estimated level of preparedness that people have to face volcanic risk.

Methodology

Participants

In order to determine the statistical representativeness of the sample size of the communities around Popocatépetl we performed a statistical test (Duffau, 1999). By considering the total population of the surveyed communities (67,738 people), a confidence level of 95%, and standard deviation of 3%, a minimum of 202 people would have to be considered. To assure this degree of confidence, we interviewed 200 people varying in age from 18 to 78 years. However, this sample size was reduced to 192 adults aged 18 to 60 years. The sample includes 84 men and 108 women who live near the volcano Popocatépetl.

The participants were divided into four groups according to the risk zone in which they lived: Group 1 (G1) – Residents living in zone 1 described in the introduction (15 km or less from the volcano crater, n = 46); Group 2 (G2) – Residents living in zone 2 (between 15 and 20 km from the crater, n = 48); Group 3 (G3) – Residents living in zone 3 (between 20 and 25 km from the crater, n = 49); and Group 4 (G4) – residents living in zone 4 (between 25 and 80 km from the crater, n = 49). All our participants belong to rural communities of a lower economic level in the Mexican population according to the 2004 census (INEGI, 2004).

To analyze the existing differences between age groups, two categories were created: 1) people from 18 to 30 years old; and 2) people from 31 to 60 years old.

One criterion for selecting respondents was that they had to have lived their entire life in the risk zone. Another criterion for the selection of the sample was that respondents had to live in low socioeconomic rural areas (see fig. 3, 4 and 5). These criteria are important for a valid comparison between people with similar particularities in lifestyle.

Instruments

To study risk perceptions, participants were asked three questions that were taken from the "Risk Perception Request" created by the Institute of Protection and Nuclear Safety from France (Bonnefous and Brenot, 1995). For the first two questions subjects, were given a list of 13 possible risks. In the first question, they had to answer how worrisome they estimated each risk using a Likert 3-point scale: 1-little worrisome, 2-somewhat worrisome, 3-very worrisome. In the second question, considering that the government had already identified preventive measures for each risk on the list provided, people had to select the five principal risks for which they thought improved preventive measures were needed. The last question was an open question (According to Cozby (2005), it is a question where participants can explain their thinking and their world view in a natural manner) about the risks they perceived as potentially damaging to themselves either in terms of personal safety or property (see Appendix 1).

Fig. 3. The picture shows a typical rural woman of low economical level of San Bernardino Tlaxcalancigo, a community surrounding the volcano Popocatépetl.

Fig. 4. Woman of San Nicolás de los Ranchos selling vegetables in the street.

Fig. 5. The Picture shows a women selling typical blouses outside in the street market.

To study coping strategies, participants were asked to answer three open questions. The first question asked respondents about strategies that they had used to cope with perceived risks that could potentially damage their homes. The second question was about the level of preparedness respondents think would be necessary to be resilient in the face of a volcanic eruption. The last question was about the coping strategies that participants think they would use in case of a volcanic eruption (Appendix 2).

Procedure

The researchers visited villages located within the four volcanic hazards zones described above over a period of two months. During these visits, adults who were in their workplaces, schools, streets, or stores were asked if they wanted to be part of a study about environmental risks. Some 94% of the people approached agreed to participate in the study; upon agreement, they were asked to answer a few questions to determine if they fulfilled the two criteria mentioned above for participating in the study. A nonprobability sampling called haphazard sampling or "convencience" sampling (technique involving interviews with participants in their natural environment and carried out in the manner and place considered most appropriate by the interviewer) was used to choose the sample (Cozby, 2005). Although this selection technique has problems inherent to sampling by convenience, related to the representativeness of the sample, a positive aspect is that it allows researchers to both find and survey respondents in their natural environment. As it is very difficult to interview a whole population, such samples bring us closer to understanding such matters as beliefs, opinions, attitudes, motivations and behavior of people in general (Kerlinger and Lee, 2001).

If potential respondents fulfilled our selection criteria, they arranged a time and location to be surveyed with the interviewer. Respondents were surveyed individually by psychology students who were properly trained in interviewing procedures. The interviewers read each one of the questions to make sure that the participants properly understood each question; then, people gave their answers to the interviewer who wrote them on an answer sheet. Because questionnaires were used instead of interviews, the interviewer bias was practically eliminated. This is inferred because the questions included in the questionnaires were either multiple choice questions or open questions; therefore, there was no way the interviewer might have suggested an answer e.g., "Are you prepared in case a volcanic eruption occurs? What would you do if this should happen?"

Our statistical analyses of the survey results comprised the Independent-Samples T-Test (Procedure to test hypotheses about means of quantitative variables. The purpose is to draw conclusions about populations parameters based on statistic observed in the sample, comparing the variance of the arithmetic means between two independent samples (Cozby, 2005; SPSS applications Guide, 1999), one-way ANOVA (analysis of variance has the same purpose of the T test, but it extends this comparison to means of more than two samples (Cozby, 2005; SPSS applications Guide, 1999), and chi-square test X^2 (The one-sample chi-square compares the observed frequencies of categories to frequencies that would be expected if the null hypothesis were true. (The one-sample chi-square compares the observed frecuencies of categories to frecuencies that would be expected if the null hypothesis were true. According to Cozby (2005), and SPSS Applications Guide (1999), the one-sample chi-square makes no assumption about underlying distributions of the data. It can only be used if the data are a random sample).

We did not distinguish between different volcanic hazards when we asked people about this issue for two reasons: 1) because we were not sure if people were informed about the different volcanic hazards, and their different preventive measures when facing risk, and 2) because the goal of this study was to look deeply into the psychological variables and not upon the physical knowledge of volcanic hazards.

Results

Risk Perception

The mean and standard deviation values for each hazard as a function of how worrisome the hazard was

perceived to be are shown in Table 1. Low mean values indicate low levels of worry, while high mean values show greater levels of worry. Volcanic eruptions were the most worrisome in Group (G1), while this risk perception is in second place in G2, in fourth place in G3 and in ninth place in G4. Recalling that G1 is the closest to Popocatépetl and G4 the farthest, here we can observe that, in contrast with Group 1, the other three groups perceived alcoholism as the most important risk.

To determine if these different values were significant for volcanic hazards (pyroclastic flows, lahars, and ash falls) between groups, we conducted a statistical analysis using a one-way ANOVA test. Results show that there are significant differences concerning G1 that has the highest level of volcanic risk perception (F-test = 7.17 *df* (degree of freedom) = 3,188 *p* (probability) =.000) of all four groups, with no significant difference between the other three groups. Analysis by gender was conducted using the T-test, and there were no differences concerning volcanic risk. The only significant difference found was in alcoholism. Here, women were more worried than men (*T* = 3.36 *df* = 190 Females, mean 2. 65 ± *sd* 0.67 and Males, mean 2.27 ± *sd* 0.87 *p* = .001).

Analysis by age groups (18-30 and 30-60 years old) was also conducted using the T-test, and the only significant difference was that the younger participants appeared to be more preoccupied by AIDS than were the older subjects (*T* = 2.007 *df* = 190 18-30 1.94 ± *sd* 0.94 and 30-60 1.67 ± *sd* 0.90 *p* = .046).

The percentages of risk selected by the participants to improve preventive measures are shown in Table 2. For instance, G1 selected volcanic eruption as the most important risk, while in G2 volcanic risk was in second place, in G3 it was in sixth place and, in G4 it was in seventh place of importance. G2, G3 and G4 reported having higher priorities for improving preventive measures against alcohol consumption. We analyzed the differences between groups with X^2 test and no significant differences were found in gender or age range for volcanic risk.

Responses regarding risks mentioned as potentially damaging people near their homes are shown in Table 3. When analyzing responses for this question, the mode of the responses is *volcanic eruption*, which was deemed as a potential principal cause of damage near the respondents' homes for G1, G2 and G3. On the other hand, in G4, accidents in factories are perceived as the principal cause of possible damage, while *volcanic eruption* is considered as the second greatest potential damage. When comparing means for this question, there were significant differences concerning volcanic risk between groups using one way ANOVA (*F* = 22.47 *df* = 3,182 *p* = .000). Said differences were observed between G1 and G2 (G1 2.8 ± *sd* 0.5 and G2 2.6 ± *sd* 0.64) against G3, which presents an inferior mean considering the other two groups (G3 2.23 ± *sd* 0.7) and against G4 which also is significantly different against the other three groups with the lowest mean (G4 1.8 ± *sd* 0.66).

Table1

Averages values of risks selected as the most worrisome

RISKS	**G 1** Mean+*sd*	**G 2** Mean+*sd*	**G 3** Mean+*sd*	**G 4** Mean+*sd*
Air pollution	1.37 ± .61*	1.48 ± .71*	1.84 ± .87*	2.22 ± .87*
Water pollution	1.61 ± .86*	1.69 ±.85*	2.02 ±.90*	2.33 ± .85*
Alcoholism	2.41 ± .86	**2.42 ±.77**	**2.53 ±.77**	**2.57 ±.76**
Earthquakes	1.74 ± .88	1.58 ±.77	1.88 ±.95	1.84 ±.96
Floods	1.26 ± .61*	1.37 ±.70*	1.71 ± .91*	1.49 ± .84*
Volcanic eruption	***2.59 ± .65****	*1.92 ± .85**	*2.16 ±.87**	*1.88 ± .93**
Robberies and aggression	1.52 ± .75*	1.67 ± .83*	2.22 ± .90*	1.93 ± .89*
Work accidents	1.33 ± .70*	1.52 ± .77*	1.57 ± .71*	1.86 ± .84*
Drugs	1.96 ± .92*	1.73 ± .82*	2.04 ± .91*	2.53 ± .77*
AIDS	1.50 ± .81*	1.58 ± .85*	1.80 ± .91*	2.31 ± .94*
Nicotine addiction	1.76 ± .82*	1.77 ± .83*	2.18 ± .86*	2.53 ± .79*
Forest Fires	2.13 ±.96*	1.69 ± .85*	1.55 ± .87*	1.82 ± .93*
Accidents in factories	1.17 ± .49*	1.27 ± .68*	1.73 ± .88*	2.06 ± .94*

Note: Bold numbers represent the highest average values.
*p< .05

Table 2

Percentage of people who wanted improved preventive measures

Risk	**G 1** **%**	**G 2** **%**	**G 3** **%**	**G 4** **%**
Air pollution	5.6	7.6	6.8	12.8
Water pollution	9.2	11.2	11.6	**14.8**
Alcoholism	12.8	**14.8**	**17.2**	13.6
Earthquake	7.2	5.2	4.8	1.2
Storms/floods	2.4	2.4	4.0	1.2
Volcanic eruption	***18.8***	*13.6*	*8.0*	*4.4*
Robbery	7.6	11.2	12.4	14.4
Work accidents	3.6	3.6	3.2	3.6
Drugs	10.4	12.4	10.4	12.8
AIDS	4.0	6.8	9.2	8.8
Nicotine addiction	7.6	8.4	7.2	7.6
Forest fire	10.8	2.4	2.4	2.8
Accidents in factories	0	0.5	2.8	2.0

Note: Bold numbers represent the highest percentages

Table 3

Percentages of people who perceived each risk as potentially damaging near their homes

Risk	**G 1** **%**	**G 2** **%**	**G 3** **%**	**G 4** **%**
Storms	4.4	6.2	0	0
Volcanic Eruption	**80.0**	**62.5**	**45.9**	27.5
Earthquake	6.6	6.2	10.8	0
Robbery	4.4	15.62	18.9	12.5
Air pollution	0	0	5.4	7.5
Water pollution	0	3.1	5.4	7.5
Accidents in factories	0	0	5.4	**30.0**
Gas accidents	0	0	2.7	0
Alcoholism	2.2	0	2.7	0
Insecurity	0	6.2	2.7	15.0
Road accidents	2.2	0	0	0

Note: Bold numbers represent the highest percentages

When analyzing results by gender, there were no significant differences between men and women concerning volcanic risk using the T-test. However, considering other risks, the T-test showed significant differences when evaluating drug (Males 1.87 ± *sd* 0.88 Females 2.16 ± *sd* 0.88 $p = .026$) and nicotine addiction (Males 1.86 ± *sd* 0.82 Females 2.24 ± *sd* 0.81 $p = .002$). In both cases women, more than men, perceived drugs and nicotine addiction as potential risks that could damage them in the environment they live in. Analysis by age range did not show any significant differences.

Coping strategies

In an open question, participants were asked about preventive measures they would take to cope with risks. Table 4 shows the answers concerning the different strategies that people said they had used in the past to deal with these risks.

To analyze different answers, we classified them in 6 categories: *doing nothing; being prepared to evacuate* (having important papers, supplies and transport ready; *following preventive measures* (following authorities' recommendations such as sweeping ashes to avoid structural collapse, keeping water sealed, not consuming food that might have been polluted by ash, covering one's mouth, etc.); *personal measures with family care* (being prepared and making sure one's family has a strategy to protect its members); *being informed* (consulting information with any media or any expert); and *religious strategies* (faith in God or paying homage to volcanoes).

As we can see in Table 4, most people in all groups had not done anything to cope with risks perceived near their homes. The percentage of answers from people who say that they do nothing increases progressively in G2, G3 and G4. When participants said that they had used a coping strategy, it was found that in G1 *prepared to evacuate* was the strategy most used to cope with risk, while following preventive measures was the strategy most used in G2 and G3.

A *Chi-square* X^2 analysis was made for gender and age-range variables. Results shown by the test according to gender categories did not show any significant differences. However, significant differences were found between the age categories (X^2 (7)= 15.3, $p< .032$). Older people tend to use strategies such as not doing anything, preparing themselves for evacuation, *following preventive measures*, and family care, more than younger subjects. However, younger people tend to use following preventive measures more than older subjects.

People were then asked about their perceived level of preparedness in facing the risk of a *volcanic eruption*. As we can see in Table 5, only participants of G1 (54% of participants) feel prepared to face a volcanic eruption, while in the other three groups people did not feel as well prepared to cope with this risk. A disconcertingly large number of people feel they are not prepared to face an eruptive event; the percentage of people who do not feel prepared increased progressively in G2, G3, and G4 (Table 5).

Analysis by gender categories did not show any significant differences. Age-range analysis did show significant differences (X^2 (3) = 7.83 $p< .049$) — younger people reported more frequently not feeling prepared to face a volcanic eruption than older people.

Finally, participants were asked about coping strategies that people thought they would use if an eruptive event were to occur. As we can see in Table 6, most people in each group said that they would leave the area. The percentages of people reporting this perceived response were higher in the two groups nearest the volcano, although they were also high in the two farthest groups. Moreover, 10% of people in G2, and 24% in G3 and G4 said that they did not know what they would do. Analyses by gender categories show that there are no significant differences. When comparing age-ranges, significant differences were found (X^2 (3) = 8.36, $p< .039$). A higher number of older people said that in the event of a volcanic eruption, they would either evacuate (older 32.8%, younger 26.04%) or stay at home (older 6.25%, younger 3.12%); while a higher number of younger people said that they would follow preventive measures (younger 11%, older 6.7%) or that they do not know what to do (younger 9.37%, older 4.5%).

Table 4

Strategies used to cope with perceived risks

Strategies	**G 1** **%**	**G 2** **%**	**G 3** **%**	**G 4** **%**
None	**34.28**	**54.54**	**69.23**	**77.7**
Follow preventive measures	14.28	22.72	15.38	0
Be prepared to evacuate	25.71	4.54	7.69	0
Personal measure with family care	14.28	4.54	7.69	11.11
Being informed	8.57	13.63	0	0
Religious strategies	2.85	0	0	11.11

Note: Bold numbers represent the highest percentages of answers

Table 5

Perceived level of Preparedness to face an eruptive event

	G 1 %	G 2 %	G 3 %	G 4 %
Not prepared	20	**50**	**60**	**64**
Partially prepared	26	20	14	10
Prepared	**54**	30	26	26

Note: Bold numbers are related to higher percentages of people's responses

Table 6

Percentage of strategies mentioned by people to cope with a possible eruptive event

Strategies	G 1 %	G 2 %	G 3 %	G 4 %
Evacuate	**84**	**66**	**42**	**42**
Follow preventive measures	8	10	30	24
Stay at home	8	14	4	14
Do not know	0	10	24	24

Note: Bold numbers represent the highest percentages of strategies used by people.

Discussion

Risk perception

Not surprisingly, volcanic risk was perceived as more worrisome by people living in the zone nearest the volcano's crater (G1) than by those in the other three groups (fig. 6 and 7 shows two of the villages nearest the volcano). Moreover, people living in zone 1 perceived volcanic risk as the most important direct risk, and as a risk that requires improved preventive measures. Nonetheless, in spite of the proximity of the other zones to the crater, especially in the case of G2, volcanic risk is not a priority for them, neither in terms of how worrisome the volcano is to them nor in terms of the perceived importance of strengthening preventive measures. However, when we asked what risks could affect them directly, perceptions changed, and volcanic risk was appraised as the most important risk potentially affecting them and their homes for G1, G2 and G3. A study conducted in Spain regarding perception of natural hazards shows different perception of danger when people assess risk for the environment or when they perceive it for themselves and the society (Martínez-Trovisco *et al*., 1997). The same can be observed in our results, with alcoholism and water pollution, which were given priority in the first two questions in G2 and G3, and then replaced by volcanic risk when risks were assessed as regarding individuals personally and not risk for society. Regarding the lowest-scored risks in the three questions, we observe that they refer to situations perceived as less important because people are rarely exposed to these kinds of risks. One exception is *earthquakes* in questions 2 and 3, estimated by G4 as being the lowest risk; however, this risk is not really low because the entire central area of Mexico is vulnerable to this natural hazard. Because in this case we are considering a random hazard that has not manifested itself recently, it is probable that subjects have formed opinions influenced by *heuristic judgments*. In this case, the disponibility heuristic states that the judgment was made according to the most recent information in the mind (Morales, 1999; Slovic, 2000). As we also observed, only G4 respondents perceived industrial risks as most important. In fact, there are some important industries in this area, and, according to our results, the proximity to these influences people's perception of which risk is considered as most potentially damaging near their homes. A recent study in Mexico, in which risk perception and its impact in levels of stress and coping strategies in people exposed to seismic and industrial hazards are compared, showed how these people exposed to industrial hazards

Fig. 6. San Buenaventura Nealtican, Mexico, one of the villages nearest of the Popocatépetl volcano. Behind is the volcano.

Fig. 7. San Nicolás de Los Ranchos, México, with the Popocatépetl volcano shown along the skyline.

reported feeling significantly more stressed; the same people at the same time, reported using more passive strategies than people exposed to natural hazards (López-Vázquez and Marván, 2003). The results of this study confirm our own, and we can conclude that the industrial hazard is a factor that causes more preoccupation and stress in individuals than do natural hazards.

When analyzing results by gender and age, we found that women are more worried about alcoholism than men. When talking with people from the villages visited, many stressed verbally their preoccupation regarding alcoholism in men, who, once the weekend has arrived, devote all their time to alcohol consumption. This situation has caused alcoholism to be perceived as a priority in the opinions of the general population. Furthermore, alcoholic beverages are used as a way of evading one's problems; this is why we deduce that this consumption is a passive strategy, used by most of the men of the visited areas as a means to obtain emotional control. It was also observed that the younger portion of the sample is more worried about AIDS than the older one. This is only an indicator that the younger generations of our sample need to reinforce their knowledge about this illness as well as its adequate prevention.

Referring to perceived risks as potentially damaging their homes, differences show that women perceived drugs and nicotine as more dangerous than men did. This could be an indicator of the risk to which they perceive themselves exposed, and that women feel more frequently threatened than men, maybe because of consumption of drugs by men. Alternatively, another reason could be the threat that it represents to their children's health.

Coping Strategies and preparedness

A surprisingly high percentage of people in the four groups have no strategy to cope with general perceived risks, and this percentage increases in those groups further from the volcano, and in the older population as well. What is important to emphasize here is the general lack of interest shown in carrying out any kind of preventive activity regarding the perceived risks. As has been observed in other studies, people exposed to risks are inclined to take preventive action if they believe that inaction, compared to preventive action, significantly increases their risk. These same people would, otherwise, remain inactive in this sense (Van der Pligt, 1996). Some studies regarding risk perception have also shown that cognitive biases have an effect on the perceived magnitude of the risk. In most cases, people will trust their inferences based on what they remember hearing or observing about the perceived risk (Slovic, 2000). Other times, people expect positive outcomes using *unrealistic optimism* (McKenna, 1993). Some people are less likely than their peers to believe in the likelihood of having bad experiences, demonstrating biases of the *invulnerability illusion* (Sánchez-Vallejo *et al.*, 1998). Such biases are a possible explanation for the high percentage of people who do nothing in face of a perceived risk. However, it is necessary further study this issue in order to understand people's responses more objectively.

When participants were asked about their level of preparedness for volcanic risk in general, in face of an eruptive event and without distinguishing specific hazards, most of them did not feel prepared; an exception is for those people living closest to the crater, where 54% felt

prepared. Furthermore, a high percentage of participants in the four groups say that they would leave the area if an eruptive event occurred. This statement reflect the serious misinformation about the preventive measures that people living in the third and fourth zones of risk (G3 and G4) should take in case of an eruption. In December 1994 (when the current eruptive period began), Popocatépetl exhibited significant eruptive activity, the instructions given by radio and television (directed to people living in zones 3 and 4) were that they should stay at home and follow specific measures for storing food and water, closing windows, covering their mouths and noses when going outside, etc. Evacuation of these zones was not suggested, and we do not have data concerning what kinds of hazards were taken into account in the information given regarding preventive measures. Another important fact to highlight is that the younger portion of the sample feels less prepared than the older portion. This shows that efforts made in previous years by the Prevention Campaigns, conducted by the local government and Civil Protection organism, in case of volcanic eruption have not influenced the younger portion of the population.

In the last question about the coping strategies people would use to face a volcanic eruption, we can also see that 10% of the people in G2, and 24% in G3 and G4 do not know what to do. In answering this question younger people indicated that they would follow preventive measures, while older people suggested that they would evacuate or stay at home. A study conducted by Gregg *et al*. (2003) about the perception of volcanic risk of people in Kona communities from Mauna Loa and Hualalai volcanoes in Hawaii showed that individual preparedness measures are limited to simple tasks concerning domestic emergencies, whereas measures specific to hazardous events such as volcanic eruptions are seldom adopted. In this study, the authors concluded that the long intervals of time between the occurrences of damaging lava flows in Kona have contributed to lower levels of awareness and risk perception of the threat from lava flows. A study made in New Zealand shows that the direct experience of people exposed to a volcanic risk does not necessarily result in better preparedness (Paton *et al*., 2000). Therefore, the time passed since the last eruption, and the lack of good personal information about preventive measures, may account for some of the reasons that make people feel unprepared for the risks of a possible eruptive event. Furthermore, it has been observed in other studies that, even when a hazard is well understood, the link between perceived risk and preparedness is weak and is mediated by additional factors such as self-efficacy, coping strategies and psychological bias, that are not studied here and would be pertinent to further studies (Paton *et al*., 2000). A study (Unpublished data of López-Vázquez and Patiño Terreros) made in these same communities near Popocatépetl referring to communication of risks shows that a high percentage of the population still do not know the specific preventive measures and signs used to face a volcanic risk. In this ongoing study, a higher degree of ignorance regarding these factors was observed among the younger population many of the warnings indicators and signs largely remain uncertain or forgotten in people's minds, because the hazards information provided has not been updated in the past seven years. Furthermore, people show a low degree of participation with the relevant institutions and manifest a high degree of distrust in government authorities.

We also observe in Table 6 that, in contrast with Table 4, a much larger number of participants said that they would evacuate in the case of an eruptive event. This contrast could be due to: a) primarily the psychological impact of the question; because in the first case the subjects were not induced to a volcanic risk, and in the second case, the question was related specifically to actual volcanic activity; b) taking the previous hypothesis into account, while answering the question presented in Table 4, this contrast could have been due to possible effect of the *overconfidence* bias, which may cause people overestimate the importance of the risk; and c) in this same question, subjects may have been referring to what they have done in the past (possibly not evacuating), but related it to what they plan to do in the future in case of an eruption (Table 6).

Conclusions

In conclusion, we observed that perception of risks differ depending on the risk zone in which subjects live and also on people's personal priorities. Taking into account that we are referring to people with a low economic status, their priorities are related to difficulties posed by their economic status. Social factors also have to be taken into account when considering the vulnerability of a population exposed to hazards (Cutter *et al*., 2000; Blaikie, 1994).

Risk perception changes according to people's impressions of possible direct damage to their own lives and property. A high percentage of people exposed to the volcanic risk of Popocatépetl do not feel prepared to face an eruptive event, and they are not well informed about preventive measures they should take to cope with a potential contingency. Such findings emphasize the need to reinforce hazards information campaigns regarding volcanic risk in communities vulnerable to direct damage in the event of a major eruption of Popocatépetl volcano. To achieve that goal, a major challenge of risk communication is to make sure that the information furnished is clear, meaningful, and understandable to

recipients, and that the suggested preventive measures correspond appropriately to the risks to which people are exposed (Paton *et al*., 2000).

One of the limitations of the present research is that we did not ask the participants if they had children or other dependents living at home. The consideration of such additional household members could have been an important influence on their opinions. This is an aspect that should be considered for further investigations. Another limitation was the non probabilistic method used to select the sample population to be surveyed. However, we could not employ a more sophisticated method because the communities at risk were small, economically poor, and located in areas of difficult access. In any case, it is necessary to continue studies of people's risk perception of volcanic hazards posed by Popocatépetl. Additional investigations should use a larger sample size and include a more variables and more specific information that could contribute to a more the comprehensive understanding of the diverse phenomena and factors involved in a study of natural hazards related from a perspective of social psychology.

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Appendix 1

Questions on Risk Perception

Q.1. We are going to cite a number of environmental problems. According to you these problems are: 1 little worrisome, 2 somewhat worrisome, 3 very worrisome. Write your answer in the first column of the table below.

Q.2. Select the five principal risks in which you think that it is necessary to improve preventive measures. Write your answers in the second column of the table below.

RISKS	Q. 1	Q. 2
Air pollution		
Water pollution		
Alcoholism		
Earthquakes		
Floods		
Volcanic eruption		
Robberies and aggression		
Work accidents		
Drug		
AIDS		
Nicotine addiction		
Forest fires		
Accidents in factories		

Q.3. Could you tell us if you are afraid of any risk that could damage you near your home? If yes, which one?

Appendix 2

Questions on Coping Strategies

Q.4. What have you do to cope with the risks you have mention?

Q.5. Do you feel prepared for an eruptive event?

Q.6 What would you do if an eruptive event occur ?

E. López-Vázquez
Social Psychology, Universidad Autónoma del Estado de Morelos; UNISEP Departamento de Psicología, Pico de Orizaba No. 1, Col. Volcanes; 62350 Cuernavaca, Morelos, México.
**Corresponding author: esperanzal@uaem.mx*