Changes in geographic clustering of post-traumatic stress disorder and post-traumatic growth seven years after an earthquake in Cauquenes, Chile

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Abstract

Recent findings indicate that both disruptive Post-Traumatic Stress Disorder (PTSD) and healthy Post-Traumatic Growth (PTG) responses have some spatial distribution depending on where they are measured and the different degrees of exposure that people may have to a critical event (*e.g.*, earthquake). Less is known about how these responses change as a function of space and time after these events. The objective of this study was to enter deeper into this relationship analysing how PTSD and PTG responses vary in their spatial distribution 6 and 7 years after an earthquake (such as the one that occurred on 27 February, 2010 in Cauquenes City, Chile). Spatial analyses based on Geographic Information Systems (GIS) were performed to detect global and local geographic clustering. Investigating 171 (2016) and 106 (2017) randomly selected adults from Cauquenes, we demonstrated that 7 years after the event only 4 variables were spatially clustered, *i.e.* personal mental strength, interpersonal relations, new possibilities and appreciation of life), all of them PTG dimensions; This result contrasted with the situation the previous year (2016), when 7 variables were clustered (total PTG, spiritual change, new possibilities, appreciation of life, PTSD symptoms, PTSD reactions and PTSD in total). The spatial identifications found could facilitate the comparison of mental health conditions in populations and the impact of recovery programmes in communities exposed to disasters.

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Introduction

During the course of life, people can be exposed to critical events, such as natural disasters, illness, unemployment, even the death of a loved one. Such events test adaptive capacity and can alter people's mental health both for the short and the long term (IASC, 2007). Not all people face these events equally, nor is their resilience the same. For example, an earthquake can elicit disruptive responses, *e.g.*, Post-Traumatic Stress Disorder (PTSD), anxiety, depression, substance abuse and suicidal ideation, although healthy responses, such as Post-Traumatic Growth (PTG), social support and resilience are also likely to emerge (Bonanno *et al.*, 2005). These authors (2010) and Cairo *et al.* (2010) indicate that disasters produce at most 30% of disruptive responses. Variables of exposure-protection to the event, such as social support, being farther from the epicentre or having fewer material losses (Leiva-Bianchi *et al.*, 2017), are related to greater psychological well-being and the emergence of healthier responses, such as engagement in interpersonal contacts, beliefs about mutual helpfulness and benevolence (Kaniasty, 2012).

In this sense, healthy responses of the PTG type are directly related to PTSDs. This dependency is presented as an illusion of impact control in the face of a difficult event (Hobfoll *et al.*, 2007). Likewise, from the perspective of psychosocial impact, healthy responses are considered to correspond to the absence of disruptive responses and the appearance of adaptive responses (Leiva-Bianchi *et al.*, 2017). This adaptation can be successful if the strategy is appropriate for the stressful event to which the individual is exposed (Bonanno *et al.*, 2004; Cheng, 2001). Furthermore, both the absence or presence of these responses and the exposure-protection before the event can be organized into continuums of healthy-disruptive and exposure-protection responses, respectively. Four types of impact combine them: resilience (to respond in a healthy manner when exposed to a particular event), trauma (to respond disruptively when exposed), safety, *i.e.* to be a bystander (to respond in healthy manner when protected) and paradoxical (to respond disruptively when protected from the event) as proposed by Leiva-Bianchi *et al.* (2019).

Impacts can have different trajectories over time (Bonanno, 2004), which makes the prevalence of disruptive or healthy responses vary according to when they are measured (Bonanno *et al.*, 2010;

Milliken *et al.*, 2007). Recently, it has been discovered that both disruptive and healthy responses have a special distribution that depends on where they occur and the different degrees of exposure that people may have before a shocking event (Leiva-Bianchi *et al.*, 2019). Likewise, people may be exposed to more than one event of a similar nature at different times, in these exposure time periods, both healthy and disruptive responses can coexist in the same person (Morland *et al.*, 2008; Morgan *et al.*, 2011; Leiva-Bianchi *et al.*, 2017). Natural disasters occur frequently in Chile (*e.g.*, earthquakes and tsunamis in 2010, forest fires in 2017 and droughts in 2012-2019) and when their size and severity are considerable with large number of people affected, disaster areas are decreed by the government (Diario Oficial de la República de Chile, 2010; 2017; 2019). The objective of this study is to enter more deeply into the interaction between space and time that the disruptive or healthy responses have after a critical event such as a natural disaster. For this, the frequency and spatial distribution of PTSD and PTG responses are compared, six and seven years after the earthquake of 27 February, 2010 (27F) in the urban nucleus of Cauquenes in Chile.

Materials and methods

Study site and impact

The study was conducted in the urban centre of Cauquenes,

Maule Region, Chile (Figure 1). The city is made up of the following sectors and villages: the city centre (downtown) which concentrates the commercial activities in combination with the oldest residential sectors; in the Northwest, the "Los Poetas" and "Bombero Venegas" suburbs, which are working-class residential sectors with medium urban development; in the Northeast, the "Fernández" suburb is a residential sector with high poverty rates and poor urban development; and in the South, the "Estación" suburb that is a residential sector characterized by the higher income and greater urban development.

The registered effects of the 27F earthquake in the county according to the post-earthquake survey of the Ministry of Planning (Ministerio de Planificación, MIDEPLAN, 2010) indicate that 25.1% of the population experienced no damage, 41.3% minor damage, 16.2% major damage and 17.4% saw a total loss of their dwellings. By 2016, data collected for this study indicate that 24.6% of the population experienced no damage, 32.2% minor damage, 19.9% major damage and 23.4% lost all of their dwellings. For its part, in 2017, it was registered that 7.5% experienced no damage, 17% minor damage, 30.2% major damage and 45.3% saw a total loss of their dwellings.

Participants

From a total of 13,695 dwellings distributed over 466 blocks in the urban area of the Cauquenes borough (INE, 2019a), a sub-sample or two-stage sample was built (the first stage was the urban blocks and within these the dwellings). The participation of a suit-
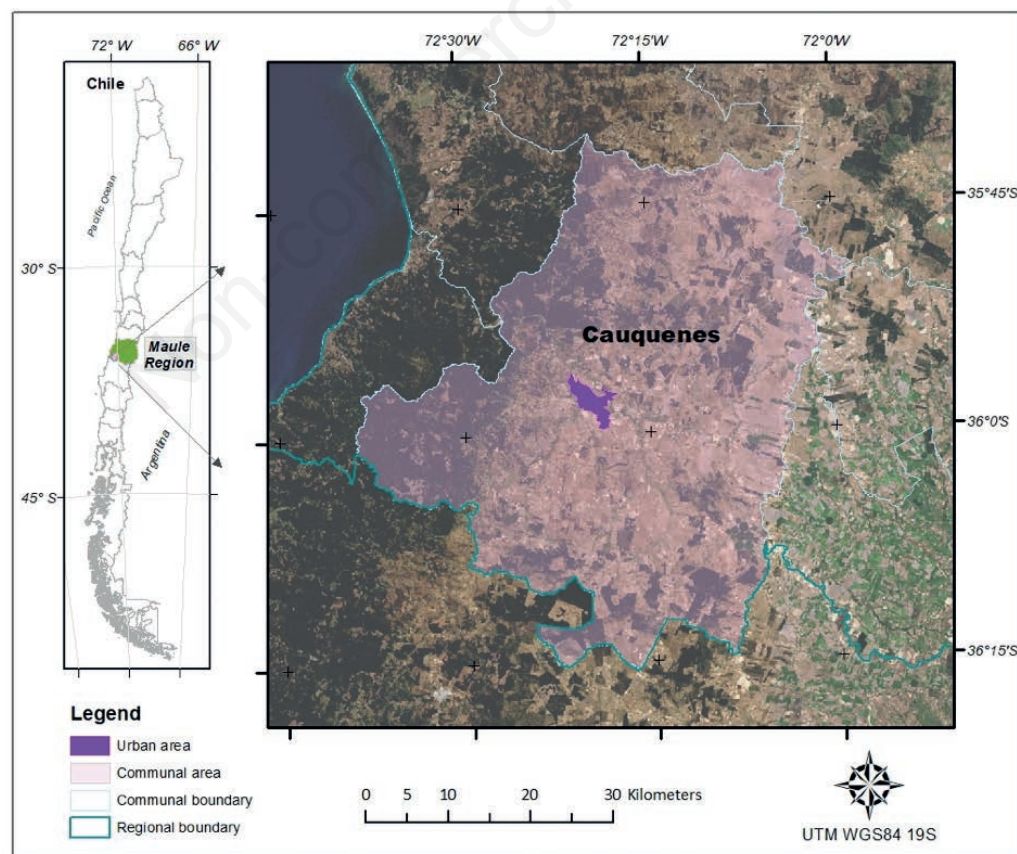

Figure 1. Localisation of the study area.

able informant was required for each dwelling, *e.g.*, a person over 18 and head of the household. The data were collected longitudinally (same house and same person) during the months of July and September of 2016 and 2017. The estimates were subject to a maximum error of 7.5%, a confidence level of 95%, a power of 80% and a maximum variance of 50%. In 2016, 171 people (65.5% women) participated and in 2017, a total of 106 people (70.8% women) (Table 1). The age group with the highest frequency was the >65 years age-group (33.3%) in 2016 and the same (36.8%) in 2017. Although 38% of the original sample was lost in the survey application in 2017, this percentage is within what is acceptable as indicated by the National Institute of Statistics (Instituto Nacional de Estadística, INE, 2019b). On the other hand, the intercensal growth rate between 2002 and 2017 was -0.12%, indicating only a small decline in the population size (INE, 2020). Therefore, the 2016 and 2017 samples were equally representative, with only a marginal number of people leaving the area after the 27F earthquake.

Assessment of severity of symptoms

The Short Post-Traumatic Stress Disorder Rating Interview (SPRINT-E) and Post-traumatic Growth Inventory (PTGI) were applied after voluntarily agreeing to participate. SPRINT-E is a scale with 3 items that measures PTSD symptoms (*e.g.*, re-experimentation; avoidance; hyper-arousal) and 9 items that measure other reactions expected after a disaster (*e.g.*, adjustment to daily life; alcohol use; drug use; suicidal inclination). Each symptom or reaction has a scale ranging from 0 up to 4, which means a possible maximum of 48 points. A total of 9 points or more, including 3 measures with at least 3 points, is considered a case of PTSD (Norris *et al.*, 2008; Leiva-Bianchi and Gallardo, 2013). PTGI, on the other hand, is composed of 21 measures that gauge the mental growth and personal development of those having experienced a critical event such as a disaster (*e.g.*, relating to others; new possibilities; personal mental strength; spiritual change; and appreciation of life). Each item is evaluated with a scale from 0 up to 5 (105 points maximum). The growth can vary from little change (0 to 50 points); moderate change (51-74 points); or major change (>75 points) (Tedeschi and Calhoun, 1996; Leiva-Bianchi and Araneda, 2015).

The post-traumatic effects geodata base

The study referred to a georeferenced database containing all the relevant geo-information for Cauquenes (streets and urban blocks obtained from Military Geographic Institute of Chile). The cartography and satellite images from the Worldview satellites (https://www.maxar.com) were built in ArcGIS software v. 10 (ESRI, Redlands, CA, USA). All information about post-traumatic effects collected by survey was georeferenced into the database using the residential address recorded during the psychological evaluation of every single individual. Thus, two Geographic Information Systems (GIS) collections (one for each study year) were created using georeferenced points as representative elements for individuals linking all psychological evaluation data in a thematic table (Mena *et al.*, 2017). These GIS datasets were later used as the main input data for the calculation of post-traumatic rates and the spatial autocorrelation analyses.

Global and local spatial association analyses

Moran's *I* statistic was calculated according to Zhao *et al.* (2013) and Chen *et al.* (2015) in order to identify the variables

under study that present a global clustering. The index values can range between −1 to +1, where a value near +1 indicates that the variable tends to cluster, meaning that values registered for participants at one location are similar between neighbours; and a value near -1 indicates that higher and lower measurement values are heterogeneously distributed in the analysed area. The threshold distance used in the analyses for the searching ratio was 700 m, a distance that represent a mean size of a suburb-sector of the city.

The Gi* local statistic (Ord and Getis, 1995) was used to analyse the spatial correlation among post-traumatic indices of neighbouring participants in order to detect statistically significant spatial clusters of high value (hotspots) or the opposite (coldspots). This analysis was completed only for those psychological variables that showed a global clustered condition (determined by Moran's *I* statistic). As the Gi* statistic itself is a *z*-score, no further calculations were needed so the *z*-score and the *p*-value were used to identify where individuals with either high or low values were clustered spatially. Participants with a positive *z*-score thus corresponded to a spatial clustering of high values and those with a negative z-score correspond to one with low ones. The results can be portrayed on a map where higher (or lower) *z*-score values indicate places of more intense clustering, while *z*-scores close to zero do not indicate any apparent clustering (Getis and Aldstadt, 2004).

Results

In 2016, the prevalence of PTSD associated with the impact of the 27F earthquake was 24.6% (76.2% women), while the percentage of people with high PTG was 55% (69.1% women). By contrast, in 2017 these rates of prevalence were 46.2% (63.3% women) and 76.4% (75.3% women), respectively.

The results of the Moran's *I* statistic are shown in Table 2 for the years 2016 and 2017. As can be seen, the 7 variables under analysis in 2016 were spatially clustered, while only 4 of them were clustered in 2017. In turn, Table 3 shows the mean values for hotspots and coldspots of clustered variables detected by application of the local Gi* statistic for the two years. For the most interesting variables, maps were elaborated in order to visualize geographically the spots detected in the city context (Figure 2).

Table 1. The study population surveyed in 2016 and 2017.

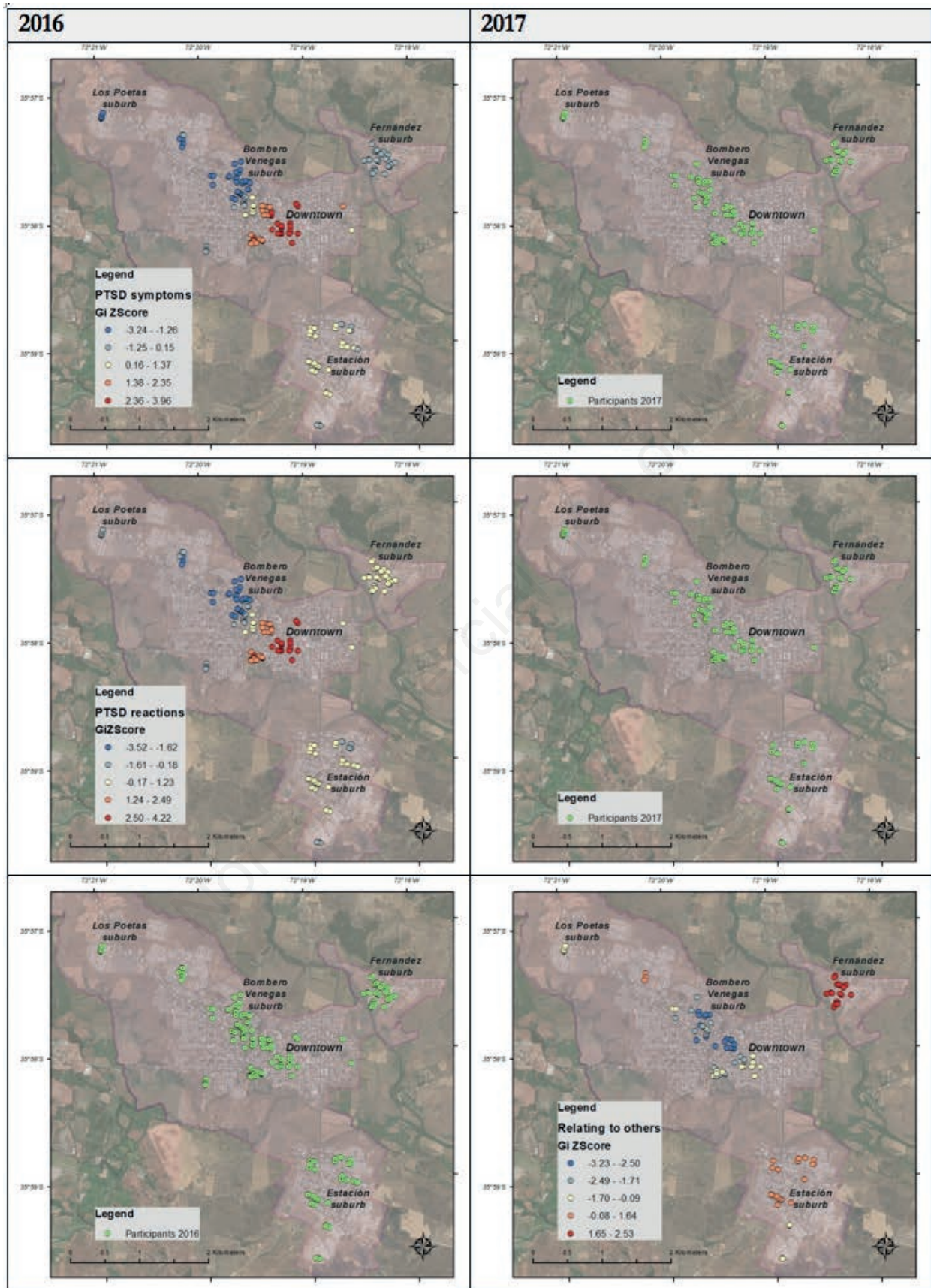| Variable	2016		2017	
	N	%	N	%
Women	112	65.5	75	70.8
Men	59	34.5	31	29.2
Age >65	57	33.3	39	36.8
High school completed	52	30.4	29	27.4
Living alone	20	11.7	20	18.9
Income level: 281-563 USD*	78	45.6	53	50.0

* United States dollars.

Figure 2. Getis-Ord Gi* statistic for clustered disruptive (PTSD) and health (PTG). Continued on the next page.
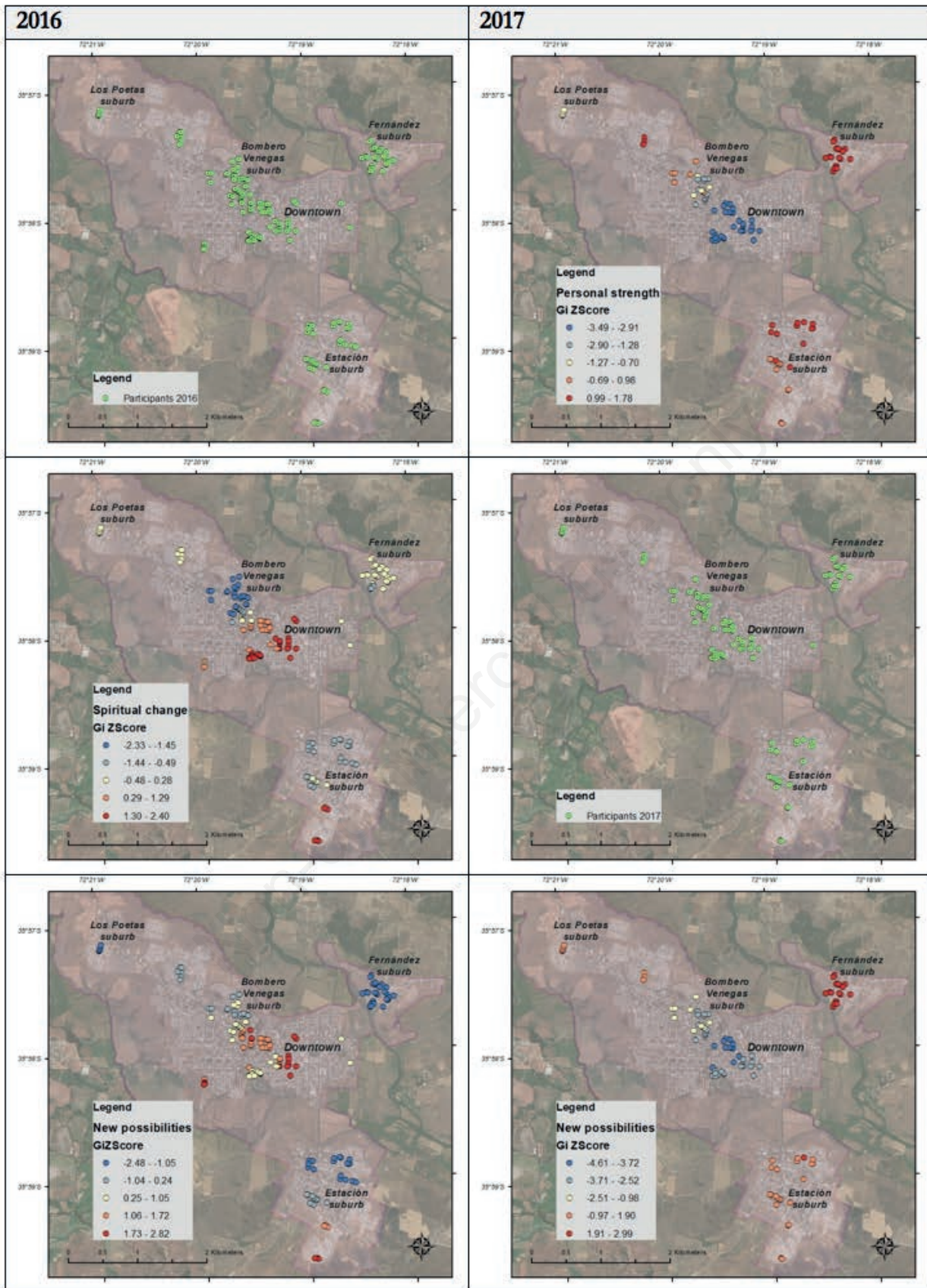
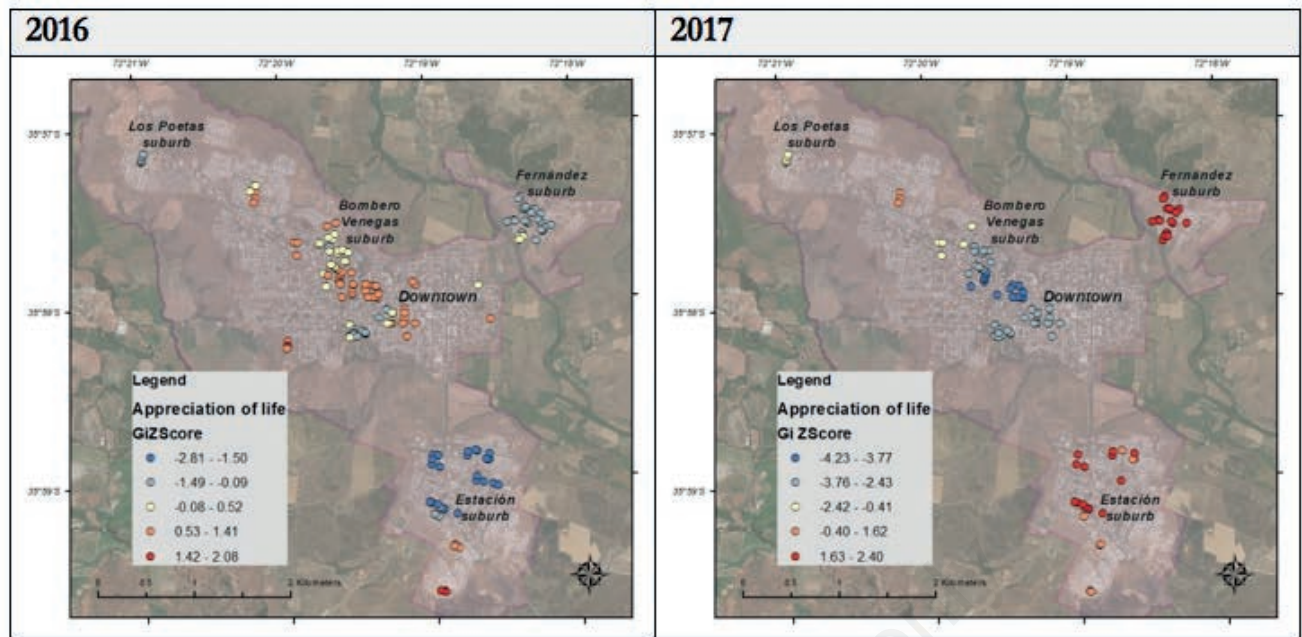Figure 2. Continued from previous page. Continued on the next page.

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Table 2. Global Moran's I result for analyzed variables in 2016 and 2017.

Variable	2016				2017			
	Index	Z-score	P-value	Pattern	Index	Z-score	P-value	Pattern
PTSD symptoms	0.1314	3.3441	0.0008*	Clustered	0.0858	1.4461	0.1481	Random
PTSD reactions	0.1698	4.2913	0.0000*	Clustered	0.1298	2.1169	0.0343	Random
Suicidal inclination	0.0274	0.8481	0.3964	Random	0.1487	2.4147	0.0157	Random
Total PTG	0.1212	3.1211	0.0018*	Clustered	0.1604	2.5949	0.0095	Random
Relating to others	0.0478	1.3189	0.1872	Random	-0.0038	0.0870	0.9306*	Clustered
Personal strength	0.0678	1.8076	0.0707	Random	0.3462	5.3935	0.0000*	Clustered
Spiritual change	0.1050	2.7080	0.0068*	Clustered	0.0842	1.4242	0.1544	Random
New possibilities	0.1797	4.5326	0.0000*	Clustered	0.2656	4.1482	0.0000*	Clustered
Appreciation of life	0.0856	2.2385	0.0252*	Clustered	0.2943	4.5920	0.0000*	Clustered
Total PTSD	0.1772	4.4712	0.0000*	Clustered	0.2224	3.5001	0.0005	Random

* statistically significant at the P<0.05 level

Table 3. Mean values for variables in 2016 and 2017 at high and low cluster areas.

Variable	2016		2017	
	High cluster	Low cluster	High cluster	Low cluster
PTSD symptoms	8.5 ± 2.6	3.2 ± 4.2	-	-
PTSD reactions	11.5 ± 5.5	3.6 ± 6.5	-	-
Suicidal inclination	-	-	-	-
Total PTG	73.4 ± 18.6	64.5 ± 17.0	-	-
Relating to others	-	-	31.24 ± 4.0	26.21 ± 4.8
Personal strength	-	-	17.82 ± 1.9	15.18 ± 3.5
Spiritual change	8.1 ± 3.1	6.0 ± 2.8	-	-
New possibilities	15.2 ± 4.8	11.5 ± 4.3	21.90 ± 2.9	18.15 ± 3.7
Appreciation of life	10.5 ± 3.4	8.7 ± 3.6	12.97 ± 1.8	10.20 ± 3.3
Total PTSD	19.7 ± 7.4	6.7 ±10.7	-	-

Discussion

The results confirm that disruptive and healthy responses are linked to the spatial and temporal dimensions after a critical event such as a disaster has occurred, and that there is a change in the geographical distribution of the responses between 6 and 7 years after the event. Previous studies have shown that disruptive responses increase when people are more exposed to the event (Leiva-Bianchi *et al.*, 2017). However, the passage of time implies a decrease in exposure, given the reconstruction of the houses and the social support received. This would allow, for example, an increase in psychological well-being and positive responses in people (such as engagement in interpersonal contacts as well as beliefs about mutual helpfulness and benevolence) (Kaniasty, 2012).

In parallel, healthy responses continue to evolve over time and space. This complements the theory of disruption trajectories. After a disaster, there is a proportion of people (*e.g.*, 30% in the case of earthquakes) who will present disruptive responses. However, most will respond in a healthy way to the event, either because they recover; that is, they undergo an initial disruption and quickly return to pre-event health levels, or because they always maintain high levels of healthy responses and do not develop symptoms of disruption (Bonanno, 2004). In this regard, these findings complement the theory in two ways:

i) Healthy responses with respect to the way people relate to others and personal mental strength appear where they were not present before, and tend to decrease where there is more exposure to the event (*e.g.*, downtown). This is explained because the most damaged places in a city are directly assisted by agents external to the same community. This could affect growth variables linked to the relation to other people and also to the control that each one has over their own environment.

ii) Responses can change their spatial distribution after 7 years of the event, as is the case of new possibilities and appreciation of life that previously tended to decrease strongly in the most exposed areas, such as the city centre (downtown). This trend could be explained by the fact that after 7 years, most of the most highly damaged sites have been rebuilt. For its part, spiritual change goes from having a greater presence in more exposed places (and less in the most protected places), to losing its spatial distribution after 7 years. This trend could be explained by the religious beliefs that initially play a very important role for the regulation of emotions, but with the passage of time and in face of positive changes in the environment (*e.g.*, reconstruction, absence of earthquakes), these beliefs cease to be strongly relevant and lose their spatial distribution (Bonanno and Diminich, 2013).

It should be noted that the evolution of disruptive and healthy responses could be affected by other disasters that occurred in rural areas near to Cauquenes City. It must be considered that 7 years after the earthquake in the region, the occurrence of forest fires caused considerable damage to people, their property and their economic activity (Diario Oficial de la República de Chile, 2017). This new event could affect the healthy and/or disruptive responses record over time (Bonanno, 2004; Morland *et al.*, 2008; Morgan *et al.*, 2011; Leiva-Bianchi *et al.*, 2017), making it possible to explain, for example, the general increase of PTSD prevalence in the city, as well as its non-spatial clustering in 2017.

Conclusions

The use of GIS spatial analysis for post-traumatic responses registered at different times and in the same population, allows mapping and visualization of changes in healthy and disruptive responses that would not be possible with other methods. The spatial identifications found could facilitate the detailed comparison of the mental health conditions in the population and show evidence of the impact of recovery programs in communities exposed to disasters. In this way, the use of this type of analysis methodology may help in assessing whether the recovery tasks deployed for the communities (*e.g.*, reconstruction, health treatments) are effective or not, allowing the use and distribution of available resources to be improved. This reveals the importance of comparing the mental health responses to a shocking event and their behaviour as a function of time, in addition to having updated geo-databases of the populations under study and their geographical context.

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