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Supplementary Online Materials

The Role of Hedonic Behavior in Reducing Perceived Risk: Evidence from Post-Earthquake Mobile App Data

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1. Earthquake and Subsequent Damage

1.1 Background

The Ya'an earthquake occurred at 08:02 (Beijing Time, UTC +8:00) on April 20 (Saturday), 2013. The epicenter was located in Lushan County, Ya'an, Sichuan, about 116 km from Chengdu, the capital of Sichuan province (in southwest China). The magnitude of the earthquake was placed at Ms 7.0 by China Earthquake Data Center.

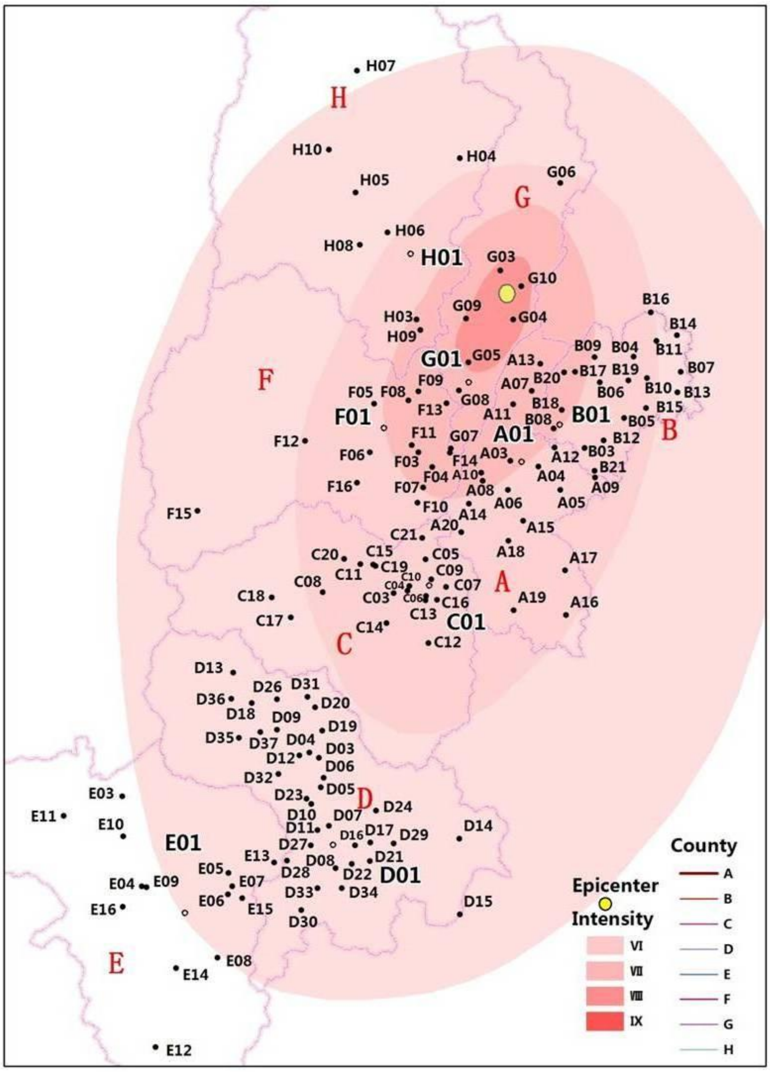

Figure S1. Geographic distribution of earthquake intensity in Ya'an prefecture. There are eight administrative and geographic regions in Ya'an. Mobile users were in 159 geographic nodes, including 1) the metropolitan city (regional hub A01), 2) 7 county seats (B01, C01,…, H01), and 3) 151 towns/villages.

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1.2 Earthquake Damage

The earthquake caused 176 deaths (90% of the total death toll) and injured 13,310 people in the Ya'an administrative region. According to local government statistics, the earthquake displaced 762,529 people (48.9% of the population, damaged 1.2 million rooms, and destroyed more than 10,000 rooms (both residential and commercial) of buildings. On average, each family faced property loss worth RMB 86,960 (USD 14,175 at May 2013 exchange rates) due to the earthquake. Based on our independent phone survey of the region (N = 1188, see S16), 68.5% of respondents reported suffering some property damage, 8.73% mentioned injury sustained by family members, and 43.4% were displaced from their home for some days (which corresponded closely to the government statistics).

County code	*County name*	*Death toll*	*People injured*	*Population Displacement*	*Estimated loss of private property (1000 RMB)*
A	Yucheng	15	1,009	140,429	537,000
B	Mingshan	2	806	75,585	7,482,000
C	Yingjing	2	369	86,265	130,000
D	Hanyuan	1	39	55,119	4,390
E	Shimian	2	42	48,950	30,000
F	Tianquan	5	1,782	166,418	6,627,000
G	Lushan	120	6,700	133,281	11,801,000
H	Baoxing	29	2,563	56,482	3,584,000

Table S1. Casualties and estimated property losses by county (1 RMB = 0.163 USD at May 2013 exchange rates).

1.3 Earthquake intensity and validation

We first verified that earthquake intensity, which we used as an instrument to measure experienced risk, corresponded to experienced damage and loss. We use earthquake intensity and distance to the epicenter as different but convergent measures of earthquake impact. One might wonder why the continuous distance measure is not preferred. This is because the impact of the earthquake was not perfectly linear, and some regions further from the epicenter suffered higher intensity that other regions closer to the epicenter, as seen from oval shaped intensity regions in Figure S1 (e.g., F04 vs. H01).

Earthquake intensity (Typical Maximum Modified Mercalli Intensity) is a categorical measure reflecting physical damage sustained after the earthquake. Notably, it is different from the Richter scale or peak ground acceleration which measure amount of energy released. According to the US geological survey, 4.0-4.9 on the Richter scale roughly corresponds to

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IV-V intensity, 5.0-5.9 to VI-VII intensity, 6.0-6.9 to VII-IX intensity, 7.0 and higher to VIII or higher. Ya'an regions suffered intensities ranging from V to IX (Table S3).

Typical Maximum Modified Mercalli Intensity (from US Geological Survey):

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

For cross-validation, we included distance to epicenter as an alternative and continuous measure of earthquake severity (note that this is an imperfect measure because the diffusion of the earthquake's destructive power was not in a perfect circle). This measure of severity is highly correlated with intensity in our data (r = -0.821, S3). As a manipulation check, we examined the inter-correlations between earthquake intensity and different forms of damage (death, injury, economic damage, private property loss, and structural damage) reported in local government statistics.

		1	*2*	*3*	*4*	*5*	*6*	*7*
1	Earthquake intensity	1	-.821**	.561**	.762**	.814**	.479**	.738**
2	Distance to the epicenter	-.821**	1	-.573**	-.654**	-.788**	-.589**	-.845**
3	No. people injured	.561**	-.573**	1	.434**	.554**	.736**	.447**
4	Population Displacement	.762**	-.654**	.434**	1	.878**	.252**	.580**
5	Economic losses	.814**	-.788**	.554**	.878**	1	.298**	.791**

6	Property loss by Family	.479**	-.589**	.736**	.252**	.298**	1	.437**
7	No. of rooms damaged	.738**	-.845**	.447**	.580**	.791**	.437**	1

**. Correlation is significant at the 0.01 level (2-tailed). Sample size = 157,358.

Table S2. Correlation between earthquake intensity and casualty and damage.

2. Mobile Phone Data

2.1 Mobile Dataset

The data in this paper was drawn from two largely overlapping datasets, mobile telecommunications and mobile internet usage. The former dataset contained 157,358 active users for the sampling period (57.96% urban). However, because not all subscribers were active mobile internet users (some may be infrequent users), the latter dataset included 73,092 active users for the week before the earthquake, and 78,895 active users for the week after the earthquake (71,820 were active in both periods). 62.44% of mobile internet users lived in urban areas; amongst urban users, 50.04% used mobile apps (some users only used non-app based internet services, e.g., via their mobile browser); amongst rural users, 41.50% used mobile apps during the sample period. Only a small sample was drawn from intensity V regions, which were combined with intensity VI regions to represent areas of moderate intensity (labeled as “VI” throughout the paper).

To maintain individual privacy, we converted all personal identifiers into anonymous unique identifiers for analysis. The data used in this study are subject to nondisclosure and legal limitations, but more details can be obtained by contacting the corresponding author. Approval for the research was obtained through the National Natural Science Foundation of China.

2.2 Basic impact of earthquake on overall telecommunications usage

Although the focus of this research is on mobile app usage, we also include some statistics and analyses of other forms mobile telecommunications usage for cross-validation purposes. Higher seismic intensity corresponded with more calls, texts, and internet usage, except in areas where telecommunications infrastructure (e.g., cell towers, fiber optic cables) were damaged (intensity IX areas), which caused network congestions (Figure S4). Overall however, telecommunications usage changes exhibit similar general patterns as mobile apps.

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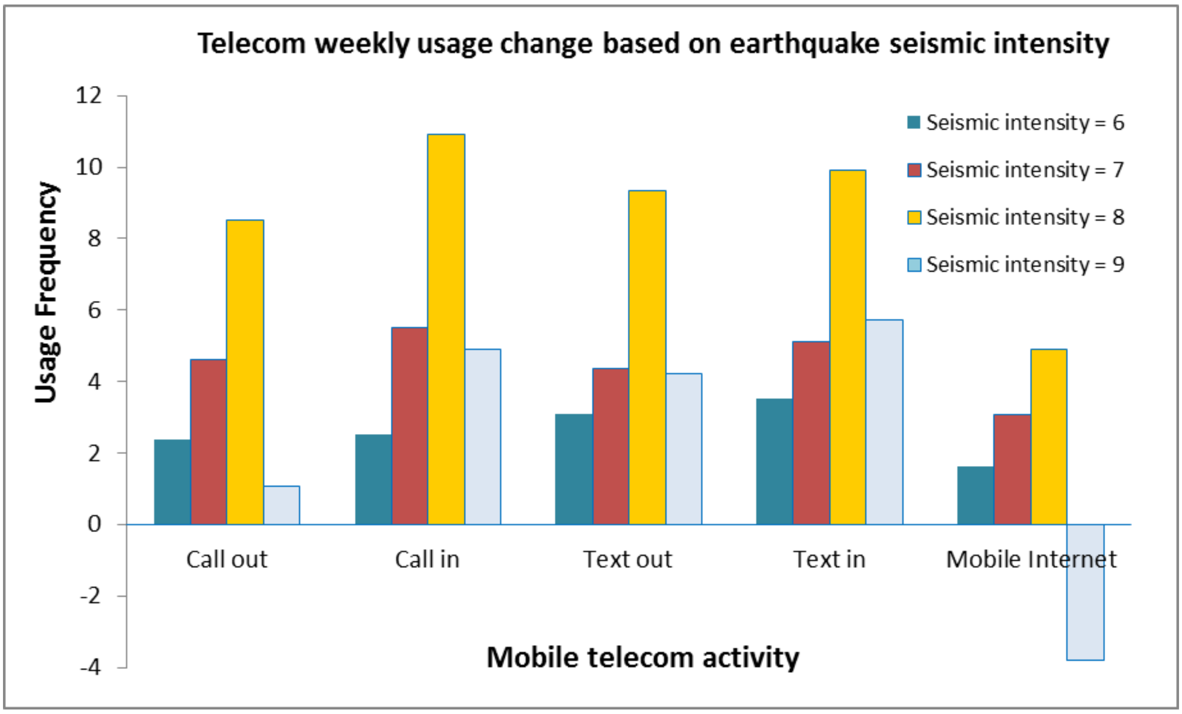

Figure S2. Change in telecom usage one week after the earthquake (by intensity level). Mobile internet usage is more severly affected under intensity IX because damage to cell towers will more adversely affect wireless internet/3G services compared to voice and text services. This is both because of bandwidth factors and also because initial emergency repairs would have prioritized on restoring more basic (voice and text) communications.

3. Mobile App Usage

3.1 Categorization of Mobile Apps

125 of the most popular and frequently used apps fall into 19 subcategories (pre-categorized by carrier to reflect each app's individual function), which we categorized into 3 major categories, communications (red), hedonic (blue), functional (green), based on each app's likely use and purpose during the earthquake.

Category	Apps
Communications	
WeChat	WeChat
Instant Messaging	Skype, YY_Voice, Mobile_MSN, Mobile_QQ, Gtalk, Mobile_Wangwang, Miliao, Yixin
Micro Blog	Sohu_Blog, Sina_Blog, Tencent_Blog
Social Networking	QQ_Space, Jiayuan, Renren, Kaixin_Web, Mobile_Tianya
Multimedia Messaging Service	WAP_MMS, Youni_SMS, HTTP_MMS, Fetion

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Email	Email189, QQ_hands_mail, ShangMail
Hedonic	
Music	I_Listen, Kugou_Music, QQ_Mobile_Music, Meters_Music, Everyday_Sounds, Mobile_Google_Music, Love_Music
Games	Farm91, Tamrac_OL, Martial_Arts_OL, Drift_Bottles, Qianlong_OL, QQ_Landlords, QQ_Game_Hall, Three_Kingdom_OL, Three_Kingdom_Killed_OL, Three_Kingdom_Reggie_OL, Elder_2, World_OL, Kyushu_OL, Tragedy_OL, Heaven_OL, Jermaine_O'Neal_Game_City, Kingdom_OL, Loyalty_OL, Flush_Phone, Pearl_of_the_Three_Kingdoms, Love_Game
Video	Kankan, Mobile_Thunder, National_telecine, PPStream_Mobile_version, Kankan_Mobile, UC_Video, Letv, Panda_Video91, Phoenix_Video, Chihiro_Television, Fantastic_Art_Film, Mobile_Youku_online, Mobile_Tudou, Mobile_TV_(Dopool), Thunderstorm_Video, No.1_Movies_Net, Tencent_Video, M_talking
Reading	Novel_Web17K, Google_Reader, TXT_Book_Download, VIVA_Mobile_Magazine, Pony, Book_Peng, Panda_Reader91, Tianyi_Reading_(official_version), Good_Books, Lazy_Audiobook, Palm_Academy, Palm_Reading_iReader
Shopping	Mobile_Paypal, Taobao_phone , Jingdong, Dian_Ping, Pudding_coupon_(Boutique_Special)
Functional	
Finance	Mobile_Securities_Star, Eastern_Wealth_through_mobile_version, Grand_Slam_Mobile_Securities, Mobile_Wisdom, Mobile_Trader
Living Services	Flight_Steward, Go_to_the_market_life, Ctrip, Dindin_Life, Word_of_Mouth_Web, Ink_Weather, I_Check, Love_City
Tools	Iflytek_input, Mobile_Guards360, Mobile_Assistant91, Sogou_input_method, Baidu_mobile_phone_input_method, QQ_Upgrade
Map & GPS	Google_Maps, AutoNavi_Map, Stock_map, GPS_positioning, Abc_map, Baidu_Maps_for_mobile
App Market	China_Appindex, Android_Market, ING_Market, AppChina, Tianyi_Space
News	Bee_News, Sina_News, Tencent_News
Browser	WAP_Browser, Dolphin_Browser, QQ_Browser, UC_Browser, Pocket_Baidu

Table S3: Categories of individual apps.

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In general, we categorized any app which is intended for interpersonal communications as communications. Hedonic apps were apps which are intended to provide leisure, diversion, or enjoyment. Functional apps were apps that had a utilitarian role after the earthquake (e.g., safety, survival, functional information search, economic well-being related, etc.). It should be noted that we did not include information search (which previous risk literature has emphasized as an important post-emergency activity) as a separate major category because not all information search was functional (e.g., searching for new music is hedonic).

We categorized shopping as primarily a hedonic behavior. The shopping apps in our dataset focused on consumer retail on-line items such as clothes and cosmetics and typically did not sell emergency supplies or food. Under normal circumstances, delivery times in China may vary from 1-2 weeks for domestic goods, however during the earthquake, delivery times may have increased to several weeks (many of the roads were limited to government/earthquake relief traffic) for non-digital products. Mobile payment was uncommon in 2013, particularly for locally available products and services in Ya'an. Consequently, it was highly unlikely that users were ordering functional items that could have immediate utility in the post-disaster environment. Rather, shopping behavior, particularly for popular consumer retail items, was more likely to be in line with the notion of retail therapy (Atalay and Meloy 2011).

We categorized web browser use as functional. Under normal, non-emergency circumstances, users may use browsers to visit websites that are also hedonic in purpose. However, during emergency situations (i.e., the first week after the earthquake, which is the data we use in the instrumental variable model), browsers are more likely to serve an informational purpose. In line with this, visits to hedonic websites fell significantly during this period; users were using their browsers to visit functional and informational sites. Some of the social media websites accessed on the browser likely served informational (e.g., reading shared news articles) rather than social communications purposes (since users were already making calls and using chat apps). Videos likely persisted because some videos on the browsers were from news sites (See section 3.3 for details).

3.2 Impact of earthquake on mobile app usage during first week

The greatest psychological impact occurred on the days immediately after the earthquake, which were reflected by the greatest change in mobile activity, which occurred during the first week. Here, we compare the app usage during the week prior to the earthquake and the week after the earthquake (Figure S6). Overall, the earthquake caused a significant increase in all of the app subcategories (*p's* < 0.001) except games ($p = 0.149$) and financial apps ($p = 0.063$).

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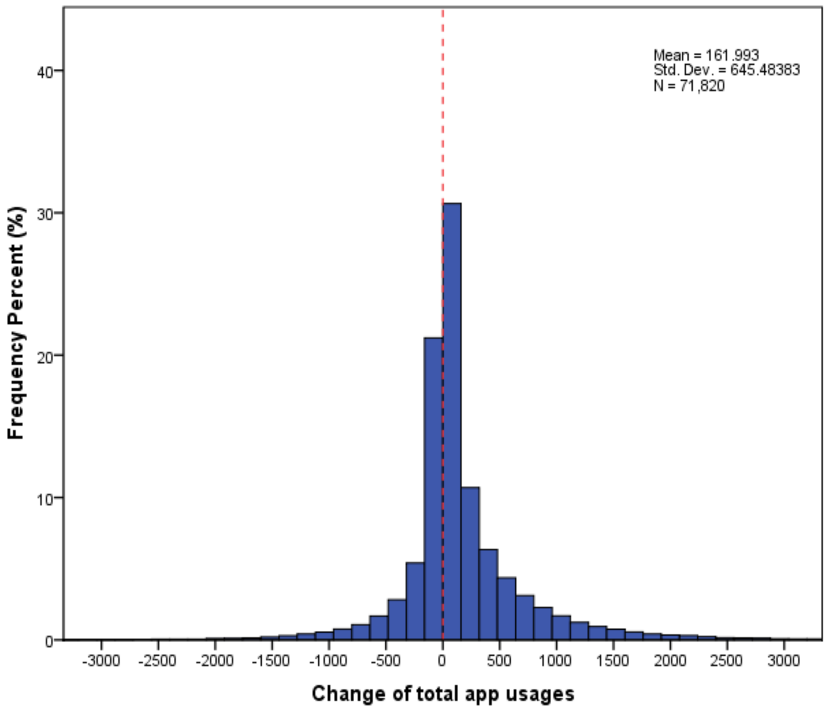

Figure S3: Change and Distribution of Overall App Usage. The first week after the earthquake, frequency of mobile app usage increased by 162 times on average (compared with the previous week). The average change was normally distributed and not driven by the habits of a minority. While 63.8% had an increase in app usage, 35.1% had a decrease, and 1.02% had no change; a distribution similar to the change in voice communications.

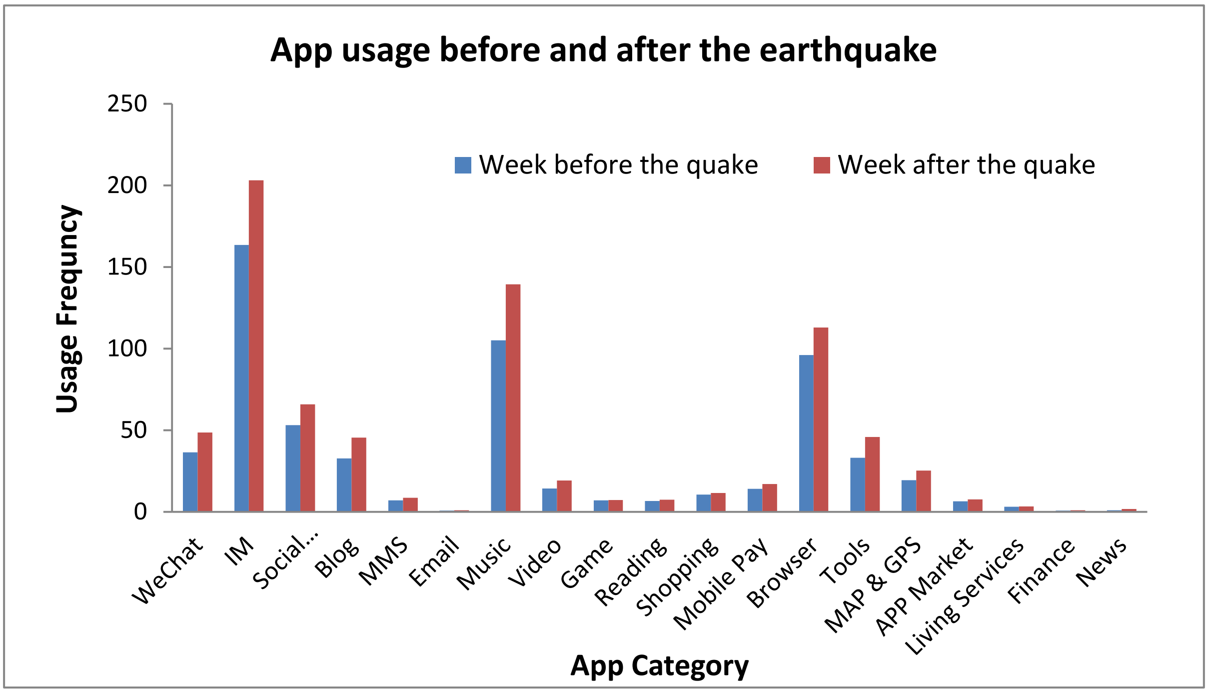

Figure S4: App usage comparison before and after the earthquake.

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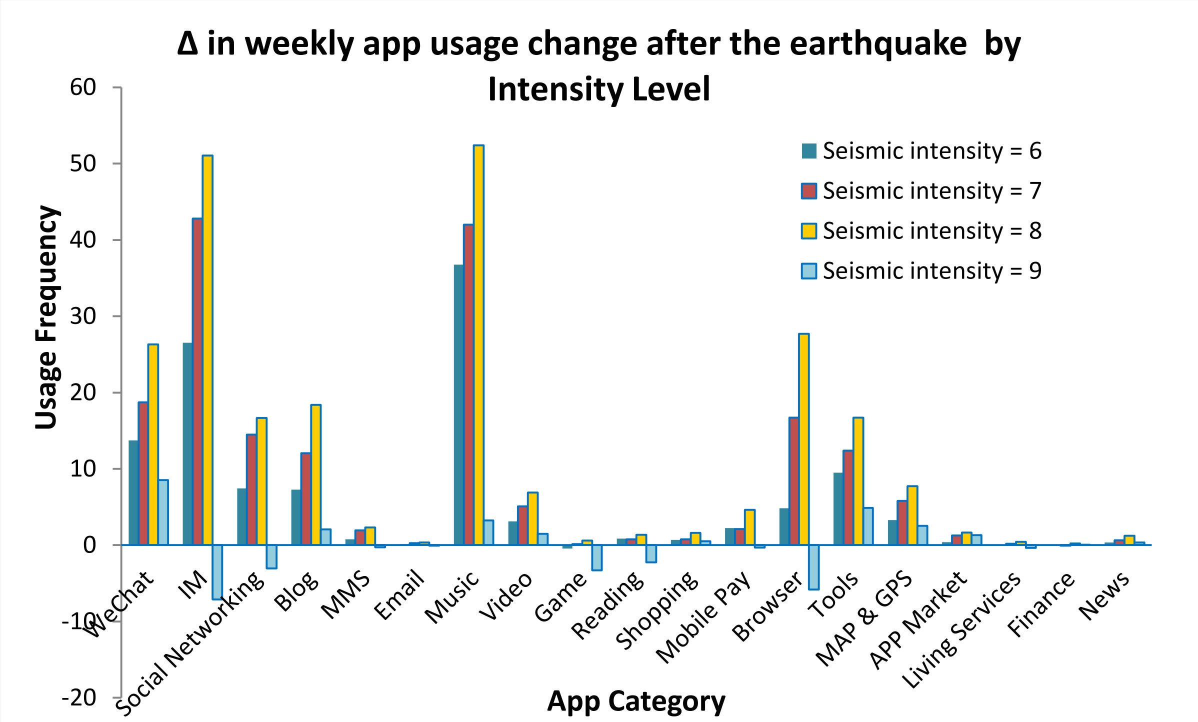

Figure S5: Relative change in use for each subcategory (previous week as baseline). In general, the average usage of mobile apps increased the week after the earthquake compared with the previous week. Usage in the most damaged areas (intensity IX) decreased significantly immediately after the earthquake, likely because of damage to telecommunications infrastructure.

3.3 Impact of earthquake on website (http) browsing

To categorize the http data, we performed a similar classification procedure for the 242 of the most popular websites visited (http's accessed). Major website categories include sports, finance, entertainment, music, games, videos, travel, education, shopping, apparel, fashion, IT products, food, parenting, furnishing, housing, cars, living services, health, media/news, reading, social networking, email, IT tools, and information services.

It should be noted that a decrease in visits to hedonic websites is not inconsistent with an increase in hedonic app usage. This pattern of results suggests that users increased the use of existing hedonic apps but did not search for new information about hedonic activities on their browser (reflected by the http visits) as much. This is also consistent with the entropy analysis which shows that the diversity of app usage does not increase after the earthquake (Figure S12), i.e., users typically increase usage of familiar, pre-existing apps.

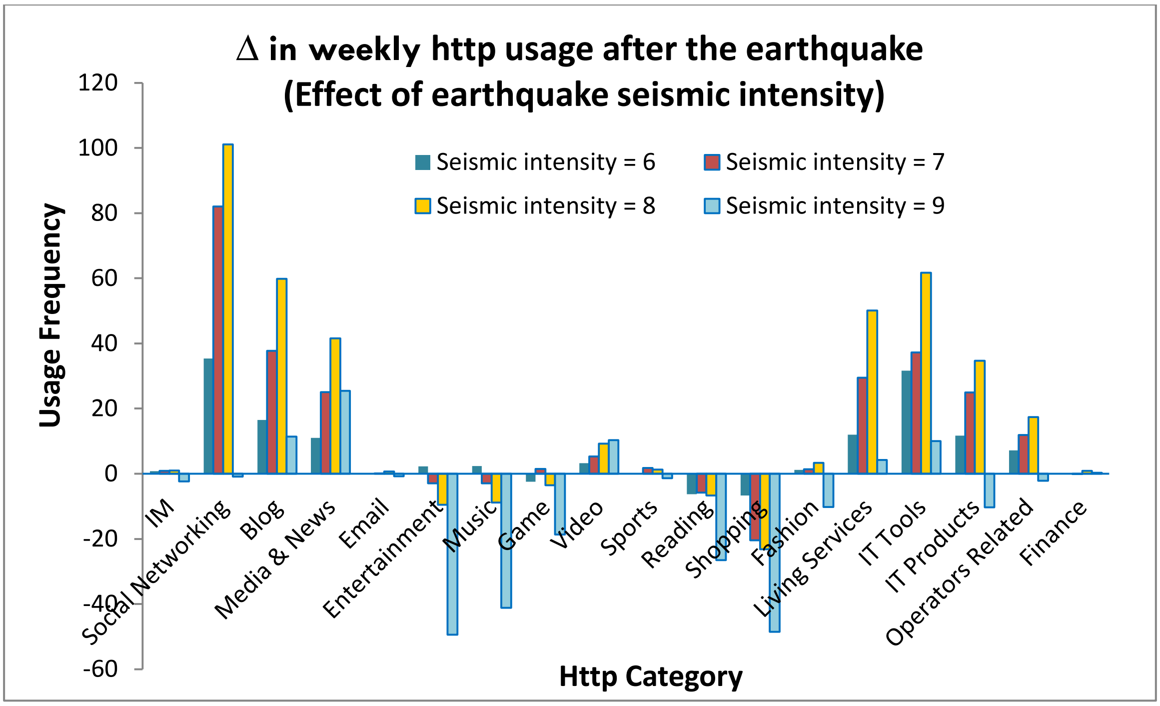

Figure S6: Relative change in browser usage (http visits 1 week after earthquake with previous week as baseline).

Overall app usage patterns exhibited two key features germane to our research interests: 1) higher intensity yielded increased app usage for all 3 category; 2) People who suffered the greatest shock (IX) saw decreased usage for the first few days after the earthquake (likely due to damage, busyness from rescue and recovery operations, and psychological shock) but a gradual increase until the relative increase was greater than and persisted longer than app usage change in other regions.

4. Robustness Checks for Model 1

4.1 Using distance from epicenter as a predictor

As a robustness check, we repeated the same analysis for Model 1 (Table 1) using an alternative measure of earthquake intensity. Instead of using the discrete Typical Maximum Modified Mercalli Intensity scale, we used distance from the epicenter, another commonly used measure of severity of earthquake. The idea of the distance measure is that greater (less) shaking occurs closer to (further from) the epicenter. Although a distance-based measure is a finer grained measure of earthquake effect, it suffers from a separate set of imprecisions since it assumes the force of an earthquake spreads out in a perfect circle, whereas the impact of the Ya’an earthquake was actually dispersed in an oval shape (S1). Thus, we just use the distance measure primarily as a form of sensitivity analysis.

Overall, this alternative measure and analysis yield consistent results; distance/severity of earthquake experience was a significant positive predictor for changes in all 3 app categories. We do however caution direct interpretations of the beta (which is small due to the unit size; meters) since the model is not linear.

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	(A) Communication Apps				(B) Hedonic Apps				(C) Functional Apps			
	Coef.	*SD*	*t*	*p*	*Coef.*	*SD*	*t*	*p*	*Coef.*	*SD*	*t*	*p*
Δ Outgoing call frequency	0.802	0.09	9.35	<.001	0.247	0.06	4.25	<.001	0.207	0.10	2.17	.030
Δ Outgoing text Frequency	0.856	0.04	21.5	<.001	0.367	0.03	13.6	<.001	0.335	0.04	7.54	<.001
Δ Activated social network size	1.42	0.25	5.75	<.001	0.783	0.17	4.67	<.001	1.41	0.28	5.11	<.001
Δ Web usage frequency	1.29	0.02	63.2	<.001	0.215	0.01	15.6	<.001	0.551	0.02	24.3	<.001
Most damaged area flag	13.8	6.70	2.06	.040	1.50	4.54	0.33	.741	9.07	7.47	1.21	.225
Distance from epicenter	**0.0004**	**<0.01**	**21.3**	**<.001**	**0.0002**	**<0.01**	**20.0**	**<.001**	**0.0002**	**<0.01**	**8.36**	**<.001**
Valid N	45,574				45,574				45,574			
Adjusted R^2	.129				.0309				.0226			
Hausman Test												
$\chi^2(6)$	355.6				112.38				107.2			
$p > \chi^2(6)$	<.001				<.001				<.001			

Table S4. First difference regression using distance from epicenter as a predictor. Dependent variables were changes in frequency of (A) communications, (B) hedonic, and (C) functional app usage between the week before and the week after the earthquake.

IV's. Change in call out frequency refers to the change of total number of outgoing calls (made by the user) between the week before and the week after the earthquake; activated social network size is the change of total number of social ties that the user called between the two weeks; change in text out frequency refers to the change of total number of outgoing text messages between the two weeks; web usage frequency change refers to the change of number of times internet is accessed between the two weeks; most damaged flag is a dummy variable for users who were in the regions that suffered infrastructure damage (intensity IX); distance from the epicenter is measured in meters.

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4.2 Impact of earthquake intensity on websites (http) access frequency

Here we tested the impact of the earthquake on website visits, which as previously discussed can be thought of as a special multi-purpose app. As shown in S7, usage of communications (mainly social networking, blog, and media and news), hedonic, and functional websites changed significantly between the week before and the week after the earthquake. Using the same model (2), we estimate the impact of earthquake intensity on category of website visits (S18).

It should be noted that the significant negative predictor for hedonic http visits does not contradict our other analysis. Rather it suggests that web browsers (which is one type of app) primarily serve functional and communications purposes in the aftermath of the earthquake. As we will see next in the entropy analysis, the overall picture is that people are generally not changing the profile of their hedonic app usage by searching for new hedonic apps (which might be an important reason for hedonic http visits) but rather increase their use of extant hedonic apps.

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	(A) Communications websites				**(B) Hedonic websites**				**(C) Functional websites**			
	Coef.	*SD*	*t*	*p*	*Coef.*	*SD*	*t*	*p*	*Coef.*	*SD*	*t*	*p*
Δ Outgoing call frequency	0.78	0.36	2.18	.029	0.10	0.51	0.20	.842	1.87	0.57	3.31	.001
Δ Outgoing text frequency	1.24	0.15	8.33	<.001	0.26	0.21	1.25	.210	0.93	0.24	3.94	<.001
Δ Activated social network size	0.99	1.05	0.94	.346	-1.74	1.48	-1.17	.240	2.07	1.65	1.25	.210
Δ Web usage frequency	0.89	0.08	11.7	<.001	0.92	0.11	8.55	<.001	1.28	0.12	10.7	<.001
Most damaged area flag	-118	37.6	-3.15	.002	-6.03	1.17	-5.14	<.001	-129	59.5	-2.16	.031
Earthquake intensity	**11.6**	**0.83**	**14.0**	**<.001**	**-160**	**53.3**	**-3.00**	**.003**	**16.0**	**1.31**	**12.2**	**<.001**
Valid N	45,574				45,574				45,574			
Adjusted R^2	.129				.0309				.0226			
Hausman Test												
$\chi^2(6)$	355.6				112.38				107.2			
$p > \chi^2(6)$	<.001				<.001				<.001			

Table S5. Internet browser behavior by http visits. Dependent variables were changes in frequency of (A) communications, (B) hedonic, and (C) functional website (http) visits between the week before and the week after the earthquake. Model and independent variables were the same as model for change in app usage in Table 1.

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5. Entropy as a measure of diversity of daily app use

Here, we explored whether the earthquake had an impact on relative diversity of daily mobile app usage. This would show whether the earthquake victims were using the same apps more or were increasing the variety of apps used. We use the concept of Shannon entropy to develop a metric for diversity of daily mobile app usage as follows:

$$H(i) = -\sum_{j=1}^{m} p_{ij} \ln\left(p_{ij}\right), \quad (5)$$

where $p_{ij} = x_{ij} / \sum_{j=1}^{m} x_{ij}$, m is the total number of subcategories of mobile apps (which is 19 in our app categories), x_{ij} is the daily usage frequency of app subcategory *j* for the individual i , thus p_{ij} is the proportion of individual *i*'s app subcategory *j* usage in the total app usage. Eagle et al. (2009) used entropy to measure the diversity in an individual's social network. In our case of mobile app usage, the entropy measure captures the diversity of daily app usage for individuals. High $H(i)$ values imply that an individual more evenly uses apps in different subcategories.

Figure S12 shows the diversity of people's daily app usage by earthquake intensity level. The diversity scores for all intensity groups changed significantly only on the day of the earthquake. People who suffered the highest intensity (IX) exhibited a dynamic pattern of app usage diversity over time (less diversity during in the first few days and more diversity afterwards). However, for people who suffered lower intensity, diversity of app usage returned to and remained similar to pre-earthquake levels almost immediately after the earthquake.

There were no significant between-intensity-group differences in app usage diversity two days after the earthquake (*ps* > 0.1) for intensities V – VIII. However, intensity IX yielded greater app usage diversity than other intensity levels for one week before the difference became non-significant at *p* > .1.

Saramäki et al. (2014) found that people display a robust social signature over time in their phone calls. Our results show that the diversity of daily different app usage for individuals is resistant to change even after they just suffered the major disaster. In other words, people tend to keep the portfolio of their mobile app based activities relatively stable even after major shocks.

Another possibility is that stability in app usage diversity itself plays a role or is an artifact of people's psychological response to risk. This is consistent with previous research showing that decision makers in high pressure, stressful situations prefer familiarity (i.e., the conceptual opposite of diversity in activities; Litt et al. 2011). The precise impact of relative diversity in activities on recovery from risk experiences, however, is beyond the scope of this research.

It should also be noted that the increase in entropy on day 1 (April 20th) demonstrates that the flat lining of entropy is not because people have all reached a theoretical maximum in app usage diversity.

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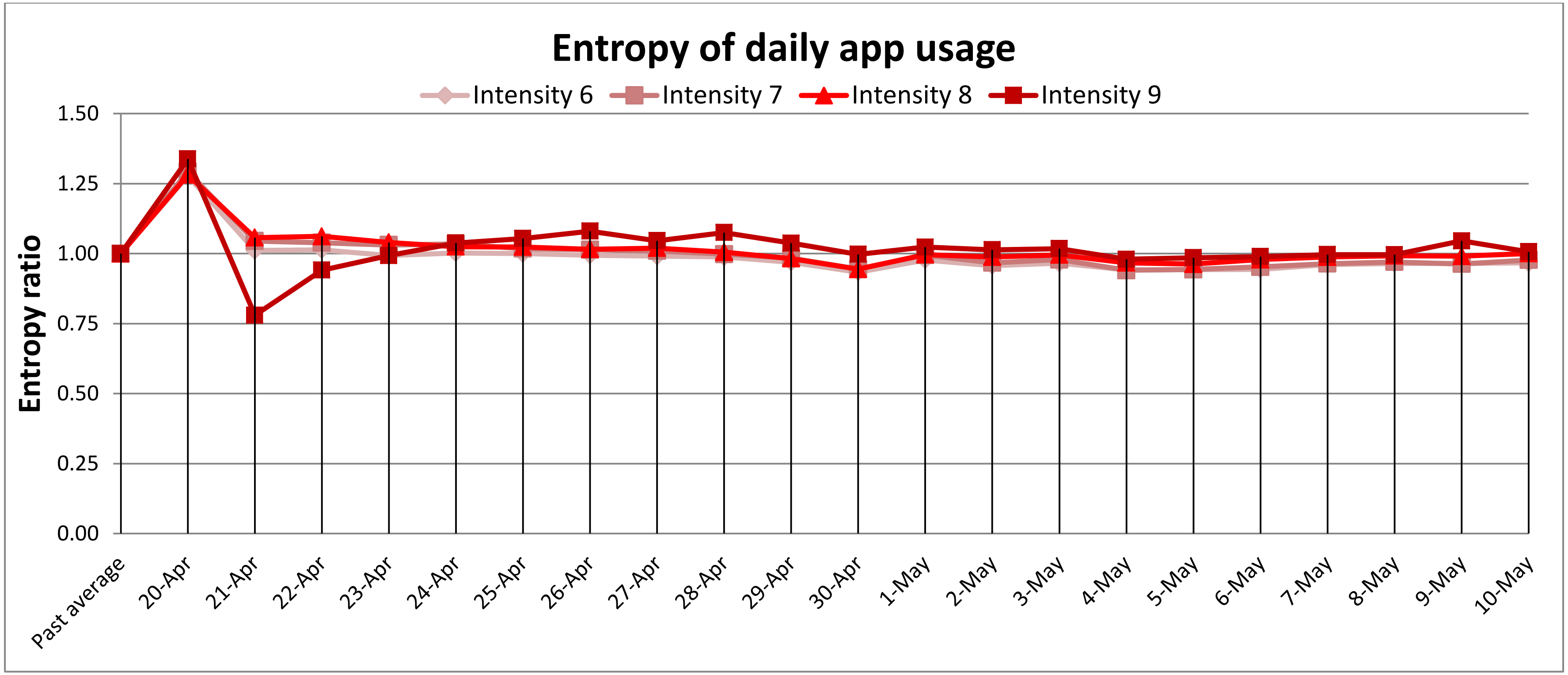

Figure S7. Entropy of daily app usage by intensity. The each of the past averages (calculated separately for each intensity level) are based on entropies for the past 7 days before the earthquake. The entropies after the earthquake are normalized by being divided by the past averages (separately for each intensity level).

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6. Impact of Mobile Behavior on Perceived Risk and Recovery

6.1 Field survey on impact of app usage on perceived risk and recovery

We conducted a phone survey immediately after the earthquake in order to create dependent variables relating to risk perception and recovery, which we link with independent variables from the mobile data (e.g., app usage) in Model 2. We conducted the phone survey by calling a stratified random sample of 2,000 people in the dataset who live in Lu Shan (the epicenter county) and Bao Xing (a neighboring hard hit county). The survey was conducted on days 6, 7, and 8 after the earthquake. We selected the hardest hit regions to provide a stronger test of the effects of communications and hedonics on perceived risk after one week of the earthquake.

Post-Earthquake Ya'an Phone Survey Questions:

1) Initial fear: How much fear did you experience at the time of the April 20th earthquake? [1 = none, 10 = a great deal of fear]
2) Reported Damage: How much injury or damage has the earthquake caused for you and your family? [1 = no harm, 10 = a great deal of harm]
3) Impact of earthquake: How much has the earthquake affected your work and living situation? [1 = no effect, 10 = very great effect]
4) Pro-active social interactions: After the earthquake, did you often pro-actively communicate/exchange information with others about matters relating to the earthquake? [1 = did not proactively communicate, 10 = often proactively communicated]
5) Perceived risk: At this point, how threatened do you feel by earthquake? [1 = no threat at all, 10 = a great deal of threat]
6)

Survey Variable	N	Min	Max	Mean	SD
Initial fear	882	1	10	7.81	2.82
Reported damaged	880	1	10	7.72	2.22
Impact of earthquake	874	1	10	7.83	2.29
Proactive social interactions	861	1	10	6.78	3.00
Perceived risk	861	1	10	6.95	2.65
Age	861	13	74	39.7	11.7
Gender	861	0	1	0.50	0.500

Table S6. Summary statistics of survey variables from perceived risk survey.

The very high response rate (43%) might have reflected respondents' need for social support and desire for sharing in the immediate aftermath of having experienced a traumatic disaster. For many, we were the first public institution to directly call them, and many may have saw the survey as a chance to share their plight with the provincial government (for whom we were conducting the survey). In general, our research assistants reported that respondents were extremely serious in answering our questions in the survey (likely because the earthquake had just happened, and victims were waiting for more government support); some even cried over the phone and needed comforting before being able to proceed with the survey.

6.2 Robustness Check for Model 2

In an alternative model to Model 2 (Table 2), we also include communication and hedonic websites (http) usage as endogenous variables based on the same models above. However, these variables are not significant predictors of perceived risk (see S14). One might wonder why earthquake intensity is used as a significant predictor in either model (S14 or Table 2). This might be due to collinearity between earthquake intensity and reported damage, which we include and is significant in the model. Reported damage is highly correlated with intensity (Table 2), and besides being continuous, is better reflection of the physical outcome of earthquake intensity (since different homes may have suffered more or less damage at the same intensity level due to other factors such as geography or quality of construction). Additionally, there may have been lower variance of earthquake intensity in the subsample (since we surveyed the two adjacent counties that suffered the highest intensity). However, these factors have no bearing on the significance of the model, which estimates the impact of the post-earthquake behaviors on perceived risk regardless of earthquake intensity.

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	Coef.	*SD*	*z*	*p*	
Constant	5.093	1.263	4.03	<.001	
Age	0.032	0.015	2.14	.033	*
Gender (Male = 1)	-0.708	0.318	-2.22	.026	*
SmartPhone (Yes = 1)	0.259	0.464	0.56	.577	
County seat (Yes = 1)	-0.543	0.320	-1.70	.090	
Reported damage	0.368	0.065	5.64	<.001	***
Activated social network size	-0.007	0.007	-0.99	.323	
Outgoing call frequency	0.173	0.222	0.78	.435	
Outgoing text frequency	-0.284	0.126	-2.26	.024	*
Internet browser usage frequency	-0.394	0.239	-1.65	.099	
Communication app frequency	**0.425**	**0.199**	**2.13**	**.033**	*****
Hedonic app frequency	**-0.312**	**0.138**	**-2.26**	**.024**	*****
Communications http frequency	0.064	0.149	0.43	.665	
Hedonic http frequency	0.080	0.146	-0.55	.585	
Observations	857				
Wald χ^2	91.31				
Prob > χ^2	<.001				

Table S7. Two-stage Tobit model with endogenous regressors for browser behavior. Perceived risk is Left-censored at 0 = 1, Uncensored = 351, Right censored at 10 = 110. Model differs from Table 2 in that it also includes communications and hedonic http browsing, but does not include functional app usage (which was not significant). This serves as a robustness check that the results from Table 2 hold even when accounting for http browsing behavior. As we can see, increased hedonic (communications) behavior still significantly predicts lower (higher) perceived risk. Http browsing has no significant effect. Sample sizes also differ because of missing http variable data for the survey sample population.

Note that Tobit regressions do not have an equivalent to the R-squared that is found in OLS regression.

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	Coef.	*SD*	*z*	*p*	
Constant	3.200	0.822	3.89	<.001	
Age	0.009	0.011	0.82	.412	
Gender (Male = 1)	-0.432	0.243	-1.78	.075	
Smart Phone (Yes = 1)	0.532	0.355	1.50	.134	
County seat (Yes = 1)	-0.540	0.252	-2.14	.032	*
Reported damage	0.222	0.055	4.05	<.001	***
Initial fear	**0.291**	**0.045**	**6.49**	**<.001**	*******
Distance to epicenter	0.000	0.000	0.64	.522	
Activated social network size	-0.004	0.005	-0.70	.486	
Outgoing call frequency	0.088	0.153	0.58	.565	
Outgoing text frequency	-0.206	0.108	-1.90	.057	
Internet browser usage frequency	-0.126	0.174	-0.73	.468	
Communication app frequency	0.266	0.179	1.49	.136	
Hedonic app frequency	**-0.289**	**0.139**	**-2.07**	**.038**	*****
Functional app frequency	0.036	0.144	0.25	.804	
Observations	804				
Wald χ^2	130				
Prob. > χ^2	<.001				

Table S8. Model 2 including initial fear covariate. Here, we ran the same instrumental variable model on impact of app usage on perceived risk while controlling for initial fear.

(Left-censored at 0 = 2, Uncensored = 589, Right censored at 10 = 213). Wald-test of exogeneity: $\chi^2(4) = 3.28$, $p > \chi^2 = .513$; No sufficient information to reject null hypothesis of no endogeneity. F-statistic against the null that the excluded instruments are irrelevant in the first-stage regression: Internet browser usage frequency, F(16, 787) = 146, Communication app frequency, (16, 787) = 159, Hedonic app frequency, (16, 787) = 155, Functional app frequency, (16, 787) = 163. All F-statistics > 10, $p < .001$, indicating that relevance condition is fulfilled for instrumental variable analysis.

Notes: Sample size is slightly smaller because not everyone answered the question about initial fear.

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7. Retrospective Field Survey on Recovery Experience

7.1 Field survey on recovery experience

The survey, which was conducted in June 2015 (on the 2 year anniversary of the earthquake, when memories of the earthquake were likely more salient due to extensive media coverage), generates additional variables that are unobservable in the mobile data.

The survey measured three important factors: 1) changes in living conditions, which we used to explore whether situational factors such as access to fixed line entertainment affected app usage, and 2) several subjective and objective measures of risk. The new risk measures are intended to serve as a comparison to the measures of perceived risk used previously (which were measured a week after the earthquake's occurrence). Although this survey was conducted 2 years on, we expected participants to have relatively accurate recollection of the events, given the magnitude of the disaster. Furthermore, these measures are likely less affected by the immediate experience of the earthquake, which might have generated stress, negative emotions, and a less objective state of mind.

We selected a random sample of 3,100 active app users in Ya'an from our dataset (sample was stratified to obtain at least 100 participants from intensity IX areas, which have much smaller populations).

Our research assistants successfully contacted 1,188 users by phone, of whom 1,134 answered all of the survey questions (complete response rate = 36.6%). 62.1% of the sample are male. The ages of the interviewees are distributed as follows: below 20 = 2.96%, 20-29 = 34.1%, 30-39 = 34.6%, 40-49 = 22.0 %, 50-60 = 6.08%, and 60 above = 0.25%.

The survey questions are as follows:

1) Where did you stay during the first week of the Ya'an earthquake? [multiple choice: i) at home, ii) outside tents, and iii) left hometown. How long did you stay there?]
2) During the first week of the earthquake, did you have any difficulties in using mobile internet (compared with before/normally)? [scale 1-10]
3) After the earthquake, how many days did you take for your living conditions to recover?
4) How much did your psychological mood recover about 1 week after the earthquake? [scale 1-10]
5) How much damage did your family properties suffer from the earthquake?
6) How much did the earthquake physically hurt you and your family members?

	N	Min	Max	Mean	SD
Stayed at home during week 1	758	1	7	6.66	1.04
Stayed in outside tents (days)	414	1	730	35.6	81.0
Left hometown (days)	108	1	180	10.8	18.8
Mobile internet difficulty	1142	1	10	6.43	1.75
Living conditions recovery (days)	1140	0	750	68.2	142
Mood recovery	1136	1	10	7.93	2.78

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Property damage	1134	1	10	3.73	3.01
Physical harm	1134	1	10	1.23	1.00

Table S9. Summary statistics of retrospective survey.

7.2 Objective and Subjective Risk Measures

Reported Damage. Reported damage significantly increased by intensity level. 31.5% people reported no damage (i.e., 68.5% reported some property damage), and 91.3% people reported no injuries in their family during the earthquake.

Distance to epicenter is significantly negatively correlated with perceived degree of property damage (r = -0.306), physical harm (r = -0.101), days of staying outside (r = -0.129), and recovery of living conditions (r = -0.196), and positively correlated psychological mood recovery (r = 0.189). Note that residential address (from which distance from epicenter is derived) is electronically verifiable and difficult to falsify since carrier also provides fixed line services. As previously discussed this measure has the advantage of being verifiable and more fine grained, but is also imperfect since the impact of the earthquake (i.e., intensity) is oval shaped.

Recovery. On average, respondents estimated it took 68.2 days for living conditions to recover after the earthquake. This varied by intensity level from ~one month for people in intensity levels V-VI, to ~2 months for people in intensity levels VII-VIII to ~6 months for people in intensity level IX. However, people's mood recovered much faster than their physical or economic situation. 79.3% experienced some recovery by the end of the first week, and 51.5% claimed to have fully recovered by the end of the first week. Mood recovery was less sensitive to intensity level.

Intensity Level	Valid - *N*	Stayed home 1st week	Stayed outside 1st week	Left home town	Living Cond. Recovery	Mood recovery	Perceived damage	Perceived physical harm
		%	*%*	*%*	*Days*	*1-10*	*1-10*	*1-10*
VI	*310*	77.1	19.0	8.39	36.43	8.71	2.71	1.09
VII	*308*	64.0	34.4	9.74	61.6***	7.79*	3.65***	1.21
VIII	*466*	59.2	41.2	10.5	73.4**	7.70	3.83***	1.33
IX	*104*	44.2	54.8	2.88	158***	7.00*	6.48***	1.27
Valid - N		*1188*	*1188*	*1188*	*1140*	*1136*	*1134*	*1134*

*$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, t-tests of mean differences between the lower and next highest level in the earthquake intensity hierarchy.

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Table S10: Effect of earthquake intensity levels on survey questions. Survey results pass basic manipulation check that higher intensity areas also reported greater perceived damage and longer duration until physical living conditions recovered.

		Days	Internet diff,	Liv. Cond. Recovery	Mood Recovery	Property Damage	Harm	Distance
Days Staying outside	*r*	1	.126*	.205**	-.140**	.318**	.189**	-.129**
	Sig.		.012	<.001	.005	<.001	<.001	.008
	N	414	395	397	397	396	396	414
Mobile internet difficulty	*r*	.126*	1	.169**	-.236**	.271**	.077**	-.129**
	Sig.	.012		<.001	<.001	<.001	.009	<.001
	N	395	1142	1136	1132	1130	1129	1142
Living conditions recovery	*r*	.205**	.169**	1	-.316**	.373**	0.041	-.196**
	Sig.	<.001	<.001		<.001	<.001	.164	<.001
	N	397	1136	1140	1136	1134	1133	1140
Mood recovery	*r*	-.140**	-.236**	-.316**	1	-.357**	-.167**	.189**
	Sig.	.005	<.001	<.001		<.001	<.001	<.001
	N	397	1132	1136	1136	1134	1133	1136
Property damage	*r*	.318**	.271**	.373**	-.357**	1	.245**	-.306**
	Sig.	<.001	<.001	<.001	<.001		<.001	<.001
	N	396	1130	1134	1134	1134	1133	1134
Physical Harm	*r*	.189**	.077**	0.041	-.167**	.245**	1	-.101**
	Sig.	<.001	<.001	<.001	<.001	<.001		.001
	N	396	1129	1133	1133	1133	1134	1134
Distance to epicenter	*r*	-.129**	-.129**	-.196**	.189**	-.306**	-.101**	1
	Sig.	.008	<.001	<.001	<.001	<.001	.001	
	N	414	1142	1140	1136	1134	1134	3100

Significance reported for 2-tailed. *.Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Table S11: Correlations between survey questions and distance to the epicenter. Columns: 1) days spent outside home, 2) internet access difficulty, 3) recovery of living conditions, 4) recovery of mood, 5) property damage, 6) physical harm to family, and 7) physical distance between home and epicenter.

7.3 Situational and Contextual Factors

Home vs. Tent. During the first week after the earthquake, 61.9% of the Ya'an residents stayed at home (at least 4 days that week), 30.0% stayed in outdoor tents, and 8.09% left their home town. Of people staying at home, 88.8% stayed at home for every day of the week; of people staying outside, 80.4% stayed in tents for more than one week. The percentage of residents staying at home (in outside tents) was lower (higher) by the earthquake intensity level, i.e., higher intensity levels drove more people to stay outside.

Gender differences. Women stayed in tents for a shorter period of time than men (p = 0.041), spent more time communicating, (p = 0.042) and found communications to more helpful in reducing stress ($p = 0.019$) than men did. Despite this, however, women's moods recovered more slowly than men's ($p = 0.019$).

Urban rural differences. Rural properties suffered more damage due to poorer quality of construction (many were self-built and not subject to earthquake resistance standards like urban apartment buildings). Rural residents spent twice as much time living in tents as compared to urban residents. However, leisure activities were more effective in reducing stress for rural residents than for urban people. It is unclear if this is because of demographic differences or because leisure was more effective for those who suffered more damage.

There were 135 iPhone users in our valid sample (11.9%); the iPhone is the most expensive phone on the market, so these users likely had higher socio-economic status. Correspondingly, they suffered less property damage ($p < 0.001$) and also reported faster recovery of living conditions ($p = 0.044$). In addition, psychological mood recovery took longer for non-smart-phone users than smart-phone users ($p = 0.042$) (though this could have been driven by socio-economic differences or by the documented effect).

App usage differences. We compared hedonic app usage (from respondent's actual mobile data) across different living conditions; during the first week after the earthquake, 61.9% of Ya'an residents stayed at home, 30.0% stayed in outdoor tents (the proportion increases by intensity level), and 8.09% left their home town. There were no differences in mobile activities across living conditions (e.g., no differences in hedonic mobile app usage for people who stayed at home or in tents) (Table S19). In other words, those that had access to alternative forms of entertainment (TV and broadband internet) used their mobile phones as much. This helps rule out the alternative account that mobile phone usage only increased in higher intensity areas because those areas suffered greater infrastructure damage and had less access to alternative sources of entertainment.

Mobile activities after and before the earthquake	Housing situation during first week	*N*	Mean difference – before vs. after earthquake	*t*	Sig. (2-tailed)
Change in communication app usage	Home	701	207	.161	.872
	Outside	389	203		
Change in hedonic app usage	Home	701	111	-.409	.682
	Outside	389	117		
Change in functional app usage	Home	701	128	-1.89	.060
	Outside	389	190		
Change in outgoing call frequency	Home	701	6.55	-.890	.374
	Outside	389	8.80		

Change in outgoing call duration	Home	701	434	-1.02	.308
	Outside	389	733		
Change in outgoing text frequency	Home	701	14.1	-.821	.412
	Outside	389	16.1		
Change in internet frequency	Home	701	9.19	.068	.946
	Outside	389	8.90		
Change in data usage	Home	701	21284	-1.12	.262
	Outside	389	33390		

Table S12: Difference of telecom and app usage between residents who stayed at home versus outdoors in tents.

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