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Personal factors influencing emergency evacuation decisions under different flash flood characteristics

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Abstract

Emergency evacuation has received more attention as an effective tool of flash flood disaster prevention that calls for systematic thinking rooted in natural and social sciences. Although personal factors influencing emergency evacuation decisions (EED) after receiving a flood warning have been widely discussed, few studies have referred this issue to the flash flood characteristics. This study explored the personal factors influencing EED under different flash flood characteristics (i.e., the frequency, occurrence time, and severity of flash floods) through field survey data. Three typical flash flood characteristics in three towns were selected as case studies. An ordinary logistical model and path analysis were used to analyze the independent influence and influence process of the personal factors on evacuation intention under the three flash flood characteristics. The results showed that personalized risk perception and warning type consistently influenced evacuation intention regardless of the flash flood characteristics, while the independent influence of flood experience and reliance on hazard information on evacuation intention was varied with the flash flood characteristics. Perceived exposure influenced evacuation intention through the mediations of flood experience when there were high-frequency, recent, and loss-causing flash floods, and of risk perception when there were low-frequency, distant, and few-loss-causing flash floods. The effect of warning type on evacuation intention was varied with the flash flood characteristics if the warning type changed from the suggestive rainstorm red warning to mandatory ready-to-evacuate warning. However, if the warning type changed from the ready-to-evacuate to immediate-evacuation warning, there was no significant difference in this effect regardless of the flash flood characteristics. Therefore, it is necessary to implement distinctive emergency management according to specific flash flood characteristics.

Keywords Emergency evacuation decisions · Warning type · Flash flood characteristics · Emergency management · Field survey

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1 Introduction

Flash flood disasters have become one of the most serious threats all over the world because of their rapid and abrupt occurrence, as well as huge destructive power (French et al. 1983; Zhao et al. 2022). The disasters have caused economic losses of 19.6 billion dollars and approximately 984 deaths per year on average since 1990 in China (He et al. 2018). To prevent the flash flood disaster, both engineering measures (e.g., dams, levees, floodwalls, and floodways) and non-engineering measures (e.g., flood warning system, floodplain mapping programs, and flood insurance programs) have been implemented around the world. As there are large quantities of flash flood disasters with widespread distribution, it is impossible and noneconomical to apply engineering measures to prevent all flash flood disasters (Bubeck et al. 2013; Liu et al. 2018). Flood warning system (FWS) as a non-engineering measure has been widely taken as one of the most effective ways to prevent flash flood disaster (Shi et al. 2020).

Currently, there are generally four parts in an FWS: (1) knowledge-based model for flooding forecasting; (2) monitoring and warning services; (3) dissemination and communication; and (4) public preparedness and response (UNISDR 2009). A lot of hydrological researches have contributed to the advancements in the first three parts of FWS. These advancements have provided the flood warnings with higher prediction accuracy and longer lead time. And the public and emergency administrators can receive reliable information promptly (Siccardi et al. 2005; Golding 2009; Verkade and Werner 2011). However, the last part of the FWS is poorly understood and rarely simulated. And the FWS sometimes fails to achieve the expected performance without public preparedness and response. To improve the performance of the FWS and prevent the flash flood disaster, it is necessary to understand the last part of the FWS from a sociological perspective (Mileti 1995; Parker et al. 2009; Du et al. 2017). Thus, more efforts should be contributed to the studies on the emergency evacuation decisions (EED) after receiving a flood warning (i.e., referring to the (4) part) in the light of socio-hydrology (Sivapalan et al. 2012).

EED after receiving a flood warning are a complex process (Karaye et al. 2020; Wong 2020). Individuals might not follow the instructions of the emergency evacuation even they have received a warning. A person receiving a warning always goes through a social-psychological process including filtering, interpretating, and evacuating risk before taking actions (Mileti 1995; Parker et al. 2009). To improve the public preparedness and the effective responses to the flash flood warnings, the personal factors influencing EED should be figured out. Three types of personal factors influencing EED were found in previous studies (Kellens et al. 2013). The first one is the situational factors, such as resident location, access to transportation, and information acquiring ability (Horney et al. 2010; Lindell et al. 2019). The second one is the cognitive factors of a person, such as emotional state, risk awareness, and values of a person about flash flood disasters (Shao et al. 2017). The third one is the socio-demographic factors including age, gender, income, social grades, and so on (Meyer et al. 2018). However, there are varying personal factors influencing EED under different flash flood characteristics (i.e., the frequency, occurrence time, and severity of flash floods).

Neglecting the impacts of flash flood characteristics leads to inappropriate identification of the personal factors influencing EED. Specifically, different flash flood characteristics can bring distinct flood experiences and memories to people. For example, the high-frequency, recent, and serious flash floods can form the dangerous experiences on the property/life losses and deep flash flood memories. On the contrary, there will be few dangerous experiences and easily forgotten memories due to the low-frequency, distant and few-loss-causing flash floods (Abebe et al. 2020; Song et al. 2021; Mazzoleni and Brandimarte 2023). These different experiences and memories can lead to differences in the personal factors influencing EED (Wachinger et al. 2013; Demuth et al. 2016; Demuth 2018; Tanaka and Shimomura 2021). Therefore, different flash flood characteristics lead to varying personal factors influencing EED. Although current studies have found that different personal factors influencing EED can result from different hazard events (Jiang et al. 2022), cultural backgrounds (Jones et al. 2013), and disaster types (Tobin et al. 2011), very few studies have explored the personal factors influencing EED under different flash flood characteristics.

The aim of this study was to explore the personal factors influencing EED under different flash flood characteristics through field survey data. Three typical flash flood characteristics in three towns located in different parts of China were selected as case studies. Specifically, we analyzed the independent influence (Sect. 5.1) and influence process (Sect. 5.2) of the personal factors on EED under different flash flood characteristics. Additionally, warning messages are the driving factors of EED, and warning type is one of the few aspects of EED over which forecasters and emergency administrators have some control (Cuite et al. 2017; Morss et al. 2018). Therefore, we specifically analyzed the effect of received warning type on EED under different flash flood characteristics (Sect. 5.3).

2 Literature review on the personal factors influencing EED

Although many personal factors can affect EED, six of them (flood experience, reliance on hazard information, perceived exposure, risk perception, responsibility, and received warning type) are discussed the most in literature (Lindell and Hwang 2008; Shao et al. 2017; Meyer et al. 2018), and thus focused in our study. Moreover, these factors are the key variables of the protective action decision model (PADM) for explaining the responses of people to threatening events (Lindell and Perry 1992; 2004). Socio-demographic characteristics were taken as control variables in EED as they could help explain emergency protection behaviors (Lazo et al. 2015; Huang et al. 2016). The current studies on the six personal factors will be discussed as follows.

Experience helps a person develop an understanding of values, feelings, and assessment in response to threatening events (Wachinger et al. 2013; Demuth et al. 2016). Although the effect of flood experience on EED has been studied (Meyer et al. 2018; Tanner and Arvai 2018; Lindell et al. 2019; Mahdavian et al. 2020), there is still no general agreement on this issue. Flood experience has a positive (Lazrus et al. 2016; Morss et al. 2018; Ohtsu et al. 2023), negative (Wong 2020; Yin et al. 2022), or no effect (Hasan et al. 2011; Hatori et al. 2023) on EED as there is a complex causal path between them (Wachinger et al. 2013; Demuth 2018).

The degree of reliance on hazard information is also an important factor for understanding EED. People living in hazard-prone areas often rely heavily on hazard information. They tend to seek information on evacuation routes and home protection, and then to incorporate it into EED (Cahyanto et al. 2016; Kyne and Donner 2018). However, the influences of reliance on hazard information on EED remain unclear in current studies. Huang et al. (2016) used a meta-analysis and found that the effect of the degree of reliance on hazard information on EED was inconsistent across different studies. Moreover, some people who rely more on hazard information are more likely to evacuate (McCaffrey et al. 2013; Liu et al. 2017; Kyne and Donner 2018), while the others are not (Kakimoto and Yamada 2016; Kyne et al. 2019; Roy et al. 2022).

Actual and perceived exposure (i.e., the distance of people's residence from the hazard source) have been found to significantly influence EED (Morss et al. 2018; Wong 2020; Acero et al. 2023; Pottier et al. 2023). Perceived exposure is more explanatory for EED than actual exposure because many individuals cannot identify whether they live in a risky location (Lazo et al. 2015; Khawaja et al. 2024). Over 80% of studies have found that exposure is positively correlated with EED (Huang et al. 2016).

Risk perception is a central factor in hazard prevention and has been defined by many ways. Protection motivation theory defines it as the individual assessment on the chance of being affected by a hazard and what the harmful consequent is (Rogers 1975; 1983). The affective dimension of risk perception, such as worry and fear, has also been discussed (Liu et al. 2017; Lindell et al. 2019; Wong 2020; Shah et al. 2024). Moreover, risk perception has been measured by personalized variables, such as personal safety feeling, the impacts of the floods on personal properties, and the possibility of interruption of daily life (Lechner and Rouleau 2019; Buylova et al. 2020; Liu et al. 2024). In general, risk perception has been proven to have a significant positive effect on EED (Liu et al. 2017; Wong 2020).

EED are also related to a person's responsibility. Individuals are reluctant to evacuate if they perceive flood disaster prevention as the responsibility of the government rather than that of themselves. However, mixed conclusions have been drawn on the effects of responsibility on protective behaviors (McNeill et al. 2013; Reynaud et al. 2013; Botzen et al. 2019; Mahdavian et al. 2020; Dillenardt et al. 2021).

Receiving mandatory early warnings is one of the primary factors influencing EED (McLennan et al. 2019). For example, people receiving a mandatory warning were found to be 24 times more likely to evacuate than those receiving a voluntary warning during Hurricanes Sandy (Daziano 2015). Receiving official warnings has a consistent and significant effect on EED (Huang et al. 2016). There is a significant difference in evacuation intention when receiving different types of warnings (e.g., hazard, impact, fear, and location-based warnings) (Cuite et al. 2017; Morss et al. 2018).

The literature reviewed had figured out that perceived exposure, risk perception, and warning type could consistently influence EED. However, flood experience, reliance on hazard information, and responsibility had limited or varying effects on EED. To explore these effects under different flash flood characteristics, three typical flash flood characteristics were taken from our case studies.

3 Flash flood characteristics in our case study regions

Three flash flood characteristics in three towns located in different parts of China (i.e., Liulin, Junchuan, and Badou) were selected as case studies (Fig. 1). The flash flood characteristics in the three towns are typical, representative, and can be easily differentiated. It will be suitable and clear to explore the personal factors influencing EED under different flash flood characteristics based on the three towns.

The flash flood characteristics (i.e., the frequency, occurrence time, and severity of flash floods) in the three towns are listed in Table 1. The flash flood frequencies in Liulin and Junchuan were higher than that in Badou. Moreover, the occurrence times of the last flash flood were recent in Liulin and Junchuan, while the last flash flood happened long ago in Badou. Finally, the last flash flood has caused significant property and life losses in Liulin,

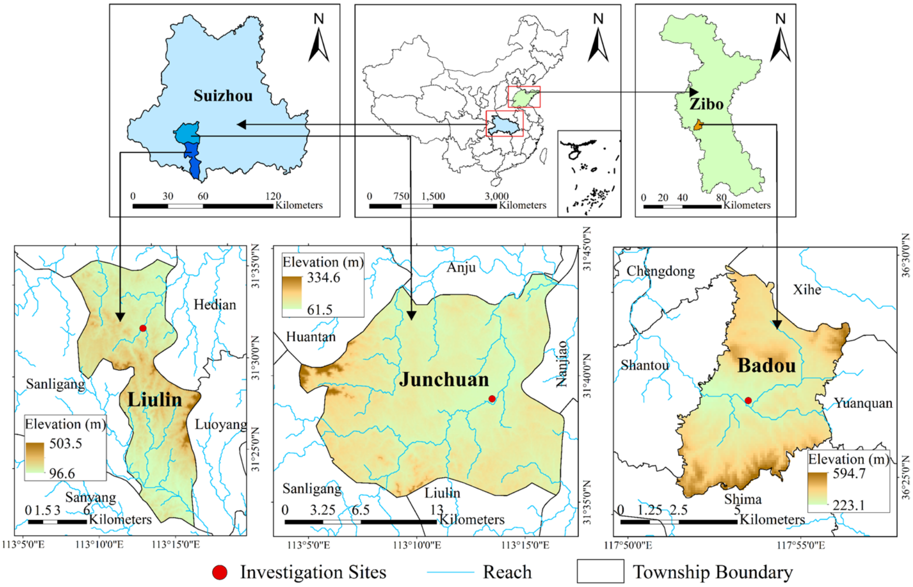


Fig. 1 The locations of the three towns (Liulin, Junchuan, and Badou)

Table 1 Flash flood characteristics in our case study towns

Characteristics	Liulin	Junchuan	Badou
Frequency	High	High	Low
Occurrence time	Recent	Recent	Distant
Severity	Loss-causing (both property and life loss)	Loss-causing (property loss)	Few-loss-causing

and only significant property losses in Junchuan, while no significant reported losses in Badou were observed.

3.1 Flash flood frequency

Both Liulin and Junchuan are located in the humid regions of southern China. Heavy rainfall in summer is the meteorological cause of their flash floods. Badou is located on the Shandong Peninsula, north part of China. Only the logging of typhoons in summer can lead to extreme precipitation and flash floods. Thus, the frequency of extreme precipitation can reflect their flash flood frequencies. The precipitation records from 1958 to 2016 in the three towns were obtained from daily dataset observed by ground meteorological stations. The extreme precipitation events in Liulin and Junchuan were taken as a whole owing to their geographically adjacency, but their flash flood characteristics are different as shown in Table 1. The last flash flood caused property and life loss in Liulin, but only property loss in Junchuan.

Table 2 The amounts (mm) and date of top ten most extreme precipitation events in Liulin and Junchuan

Maximum one-day		Maximum two-day		Maximum five-day		Maximum ten-day	
Amount	Date	Amount	Date	Amount	Date	Amount	Date
228.3	1997/6/6	293.7	2016/7/20	296.7	2016/7/20	344.9	1970/6/6
214.6	1962/7/5	246.7	1970/5/29	296.7	2016/7/21	331.5	1982/7/23
194.4	1970/5/28	232.0	1997/6/7	296.7	2016/7/22	326.6	2007/7/9
185.2	2016/7/20	229.5	1962/7/5	293.7	2016/7/23	320.8	2007/7/8
184.0	1965/8/2	228.3	1997/6/6	285.2	1982/7/23	316.0	1996/7/9
178.6	1992/5/6	214.8	1962/7/6	262.5	1962/7/8	316.0	1996/7/10
170.6	1991/8/6	213.7	1965/8/3	260.5	1970/6/1	316.0	1996/7/11
162.1	1982/7/23	194.4	1970/5/28	259.5	1962/7/9	315.4	1982/7/24
156.1	1998/5/1	192.5	1977/7/18	255.7	1970/5/31	314.9	1982/7/25
152.4	2000/6/2	185.2	2016/7/21	255.5	1970/5/30	314.8	1982/7/26

Table 3 The amounts (mm) and date of top ten most extreme precipitation events in Badou

Maximum one-day		Maximum two-day		Maximum five-day		Maximum ten-day	
Amount	Date	Amount	Date	Amount	Date	Amount	Date
222.9	1984/7/12	229.2	1984/7/12	261.2	1970/7/26	370.5	1964/8/6
152.5	1962/7/13	222.9	1984/7/13	244.3	1964/8/1	316.4	1964/8/5
146.3	1995/9/3	177.0	1963/7/20	239.4	1970/7/27	313.4	1970/7/30
126.6	1964/8/1	168.4	1970/7/26	229.3	1984/7/12	313.4	1970/7/31
125.7	2008/7/18	164.1	1970/7/25	229.3	1984/7/13	312.8	1964/8/4
125.0	1994/6/29	160.7	1974/8/14	229.2	1984/7/14	312.3	1964/8/7
120.5	1964/9/12	157.1	1997/8/20	229.2	1984/7/15	306.8	1970/7/28
118.0	1996/7/25	156.1	1962/7/14	227.2	1970/7/28	306.6	1970/7/27
116.7	1974/8/13	152.9	1995/9/3	222.9	1984/7/16	305.9	1964/8/3
116.6	1964/7/17	152.5	1962/7/13	210.4	1963/7/23	300.8	1970/7/26

The top ten most extreme precipitation events that happened in these towns were listed in Tables 2 and 3. The frequencies of the extreme precipitation events in Liulin and Junchuan were significantly higher than those in Badou. The amounts of the most extreme precipitation events in Liulin and Junchuan were almost higher than those in Badou except for the first maximum ten-day precipitation. According to the rainstorm classification standard of China, there were 32 severe rainstorms (i.e., daily precipitation of 100–250 mm) and 154 rainstorms (i.e., daily precipitation of 50–100 mm) in Liulin and Junchuan, while there were only 18 severe rainstorms and 106 rainstorms in Badou from 1958 to 2016.

More extreme precipitation events occurred after 2000 in Liulin and Junchuan than in Badou (Tables 2 and 3). In Liulin and Junchuan, two of the top ten maximum one-day precipitation events occurred in the 2000s. Similarly, two of the maximum two-day, four of the maximum five-day, and two of the maximum ten-day precipitation events happened in the 2000s. However, none of the top ten maximum two-day, five-day, and ten-day events happened in Badou in the 2000s. Only the fifth maximum one-day precipitation event took place in 2008. Overall, the extreme precipitation frequency shown in Tables 2 and 3 reflected that the flash flood frequencies in Liulin and Junchuan were higher than that in Badou, especially after 2000.

3.2 Occurrence times and severity of the last flash flood

There were a lot of flash flood events that had been recorded in the three towns. However, we only discussed the occurrence times and severity of the last flash flood, i.e., the Suizhou flash flood event on August 12, 2021 (referred to as "8.12 event") in Liulin and Junchuan, and typhoon "Lekima" from August 10th to 14th, 2019 (referred to as "8.10 event") in Badou as these flash floods left a deep impression on the local people. Although there were frequent flash floods in Liulin and Junchuan before "8.12 event", the severity of these flash floods was not extreme.

The "8.12 event" in Liulin and Junchuan occurred five months before our survey that was conducted from January 2022 to March 2022. In Badou, the "8.10 event" occurred more than two years before the survey. The occurrence times of the last flash flood in Liulin and Junchua were closer than that in Badou.

The "8.12 event" was extreme in terms of flash flood severity and caused both property and life loss in Liulin. The whole community was inundated with 1.75–3.85 m water depth. 12,899 people were affected and 6,478 people were urgently relocated. Unfortunately, 24 people died in this event. The affected area of crops was 916 hm^2 and the area of no harvest was 474 hm^2. 160 houses collapsed, 185 houses were severely damaged, and 2064 houses were ordinary damaged. The direct economic loss was more than 31.9 million dollars (Shaojun et al. 2022). The severity of "8.12 event" was moderate in Junchuan. Although the whole community was almost inundated in the "8.12 event", there were only property losses owing to the shallow water depth of the inundation. No significant losses from the "8.10 event" were recorded in Badou although the flash flood overtopped the river bank due to heavy rainfall (up to 421.5 mm from August 10th to 12th, 2019).

4 Methods

4.1 Sampling of respondents

A survey was conducted to collect residents' personal factors related to EED in these three towns from January to March 2022. As we were interested in the EED of the residents facing flash flood warnings, respondents were limited to those who lived on the flood-prone residential streets. The selected flood-prone residential streets for our survey were shown in red rectangles in Fig. 2. Towns are made up of urbanized communities and villages in China. The urbanized communities are located along the river, while the villages are sparsely located in the mountains far away from the river and are not easily submerged by flash floods. Therefore, we mainly focused on the urbanized communities in our case studies. As shown in Fig. 2, only one community and two communities were selected along the river in Liulin and Junchuan, respectively. The selected communities along the river from upstream to downstream were Heishan Community, Shitanwu Community, and Shanji Community in Badou. Xinghuaya Village was also selected in the survey owing to its proximity to a river. There is often only one main street in a community. Thus, the flood-prone residential streets can be selected directly in the communities.

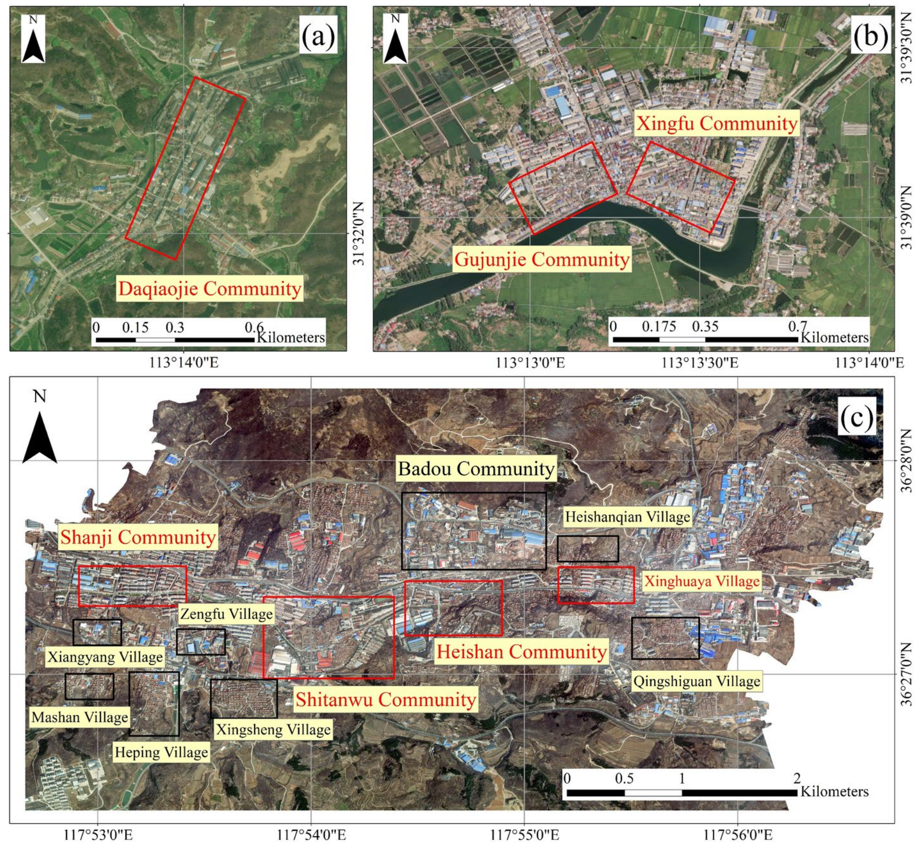


Fig. 2 The flood-prone residential streets selected for survey (represented by red rectangles) in **a** Liulin, **b** Junchuan, and **c** Badou

According to Yamane's formula (Yamane 1967), a sample size of 98 respondents was drawn at 95% confidence level and ± 10% margin of error in Junchuan and Badou, and 54 respondents was drawn at 95% confidence level and ± 14%[1] margin of error in Liulin. The total sample size of 250 was determined. Convenient sampling has been used in many studies related to flood responses owing to its easy way for implementation and low costs (Tobin et al. 2011; Weller et al. 2016; Gilliland et al. 2021; Peden et al. 2022). Our survey was conducted by convenience sampling through face-to-face interviews.

The socio-demographic information of respondents in our survey and the general population from China Statistical Yearbook were shown in Table 4. In terms of gender, the sample had a higher representation of women (46.3% male and 53.7% female) in Liulin and men (55.1% male and 44.9% female) in Badou. In Junchuan, the sample had a higher percentage of women (27.6% male and 72.4% female) than that of general population (50.3% male and 49.7% female). As weighting technology had a strong ability to eliminate the bias

[1] The margins of error were determined based on existing literature. For example, ± 7% and ± 15% margins of error have been used by Hussain and Thapa (2012) and Ullah et al. (2015), respectively.

Table 4 Socio-demographic information derived from our survey and tabulation on the population census of the people's republic of China by township

Variables	Liulin (%)	Junchuan (%)	Badou (%)
Age: 18–25	13.0	3.1	9.2
Age: 26–45	50.0	60.2	33.3
Age: 46–65	37.0	34.7	49.3
Age: 66 and over	0.0	2.0	8.2
Age Census 2010: 15–64[a]	87.6	87.5	81.3
Age Census 2010: 65 and over	12.4	12.5	18.7
Male	46.3	27.6	55.1
Male Census2010	51.4	50.3	49.9
Education: primary school diploma	3.7	3.1	8.2
Education: junior high school diploma	44.4	38.8	28.6
Education: high school diploma	29.6	46.9	35.4
Education: college degree	22.2	11.2	27.9
Length of residency: 0–10	20.4	19.4	4.4
Length of residency: 11–20	33.3	22.4	13.9
Length of residency: 21–30	16.7	23.5	33.7
Length of residency: 31–40	13.0	11.2	17.3
Length of residency: 41 and over	16.7	23.5	30.6
Floor: first floor	35.2	33.7	34.7
Floor: second floor and above	64.8	66.3	65.3

[a]Because respondents in our survey were over 18, we excluded data of respondents under 15 from census

and has been reported and employed in previous studies (Meyer et al. 2018), this technology was applied in our sample through adjusting the sample gender composition to the population profile from China Statistical Yearbook as our sample included more women in Junchuan. Only weighted results were reported in Sect. 5. The sample had also covered different kinds of people with different educational levels and lengths of residency. In addition, approximately 1/3 of the people lived on the first floor of a building. However, there were few samples from the older adults (> 65 years old). Future work can specifically focus on the special emergency response problems from older adults, such as the work of Rosenkoetter et al. (2007).

4.2 Survey measures

A questionnaire was developed to measure the personal factors related to EED of the samples, including socio-demographic characteristics, flood experience, reliance on hazard information, responsibility, perceived exposure, risk perception, and evacuation intention (Table 5). A pre-test was conducted to improve the performance and comprehensibility of the questionnaire. Questions that were difficult to be understood were rephrased or supplemented by additional questions, and redundant questions were removed.

Respondents were first asked to report their socio-demographic characteristics, including age, gender, educational level, length of residency, and floor height of residence.

Respondents were then asked if they or others (e.g., members of the family, friends, neighbors, or coworkers) had experienced flash flood events, and if so, how much previous

Table 5 Personal factors and their codes

Variables	Codes/grades
Socio-demographic characteristics	
Age	1 = 18–25; 2 = 26–45; 3 = 46–65; 4 = 66 and over
Gender	1 = male; 2 = female
Educational level	1 = primary school diploma; 2 = junior high school diploma; 3 = high school diploma; 4 = college degree
Length of residency	1 = 0–10; 2 = 11–20; 3 = 21–30; 4 = 31–40; 5 = 41–50; 6 = 51 and over
Floor	1 = first floor; 2 = second floor and above
Flood experience	
Own experience	1 = yes; 2 = no
Other people's experiences	1 = yes; 2 = no
Previous loss	1 = very low; 5 = very high
Reliance on hazard information	Mean rating of 4 items
Perceived exposure	1 = very low; 5 = very high
Risk perception	
Perceived likelihood	Mean rating of 3 items
Perceived severity	Mean rating of 3 items
worry	1 = not very worried; 5 = very worried
Fear	1 = not very fearful; 5 = very fearful
Perceived home safety	1 = very unsafe; 5 = very safe
Responsibility	1 = entirely personal responsibility; 5 = entirely governmental responsibility
Evacuation intention	1 = very low; 5 = very high

Italics represent the personal influencing factors being analyzed

property loss was caused by the last flash flood event. As the whole of communities in Liulin and Junchuan were almost inundated in the "8.12 event", and almost everyone experienced flash floods,[2] the respondents in Junchuan and Liulin were only asked about their previous property losses. In Badou, the respondents were only asked if they or others had experienced flash floods because no significant losses were recorded as mentioned in Sect. 3.2.

In this study, respondents were asked about their levels of attention to flash flood disaster related information to reflect their reliance on hazard information. Specifically, the reliance on hazard information was assessed using four questions: "To what extent do you pay attention to weather information/geological disaster warning signs/shelter location/flash flood-prone areas?" The level of attention was scored from 1 ("very low") to 5 ("very high"). The mean of the four items was obtained to represent the reliance on hazard information.

The perceived exposure was assessed by the question: "To what extent do you think your home is within the risk zone?" The responses were scored on a five-point scale from 1 ("very low risk") to 5 ("very high risk").

[2] Experiencing flash floods is defined as the respondent's neighborhood being submerged in the study.

The perceived likelihood and perceived severity were assessed using three questions. To assess the perceived likelihood, respondents were asked to express their degrees of agreement with the following statements on a five-points scale from 1 (“totally disagree”) to 5 (“totally agree”): 1. “The region may be hit by flash flood disasters.” 2. “There will be flash flood disasters in the next ten years.” 3. “Flash flood disasters have become more common in recent years.” The mean of the scores was used to measure the perceived likelihood. The perceived severity was also assessed using the mean scores of the degree of agreement of the following three statements: 1. “If there is a flash flood disaster, the flash flood disaster will damage the property.” 2. “If there is a flash flood disaster, flash flood disaster can threaten the lives.” 3. “If there is a flash flood disaster, the flash flood disaster will destroy the communities and villages including properties and lives.” Moreover, respondents were asked to score the extent of worry and fear of flash flood disasters (not at all = 1 to very great extent = 5). Finally, respondents were asked to report how much they felt safe staying at home during the flash flood periods (very unsafe = 1 to very safe = 5).

The responsibility was assessed using the question: “Do you think preventing the flash flood disaster depends more on yourself or the government?” The responses were selected based on a five-points scale from 1 (“entirely personal responsibility”) to 5 (“entirely governmental responsibility”).

In addition to the above factors, warning type is an important factor influencing people’s EED. There are two main types of flash flood warning, and their characteristics are summarized in Table 6. Meteorological warning (MW) as a suggestive warning is issued by the national weather department with a long lead time but low accuracy, while flash flood disaster warning (FFDW) as a mandatory warning issued by the local government improves the accuracy but shorts lead time. MW is divided into four levels, represented by blue, yellow, orange, and red warnings, respectively. Only after the rainstorm red warning is issued, the residents in the flash flood risk area are suggested to evacuate. However, as the rainstorm red warning is based on the predicted precipitation with high uncertainty, the residents may receive false rainstorm red warnings. And due to the widespread dissemination of the warnings through SMS, Wechat, and internet, the warnings may cover areas where flash floods have not occurred. FFDW is divided into two levels: ready-to-evacuate warning and immediate-evacuation warning. Every town and even village threatened by flash floods has its own precipitation/water level monitoring equipment. If the observed precipitation/water level exceeds a threshold, the local government will precisely communicate warning information to specific disaster locations through whistle, gong, and broadcast. To

Table 6 Summary of warning characteristics in China

Warning type	Meteorological warning	Flash flood disaster warning
Urgency	Suggestive	Mandatory
Lead time	Long	Short
Accuracy	Low	High
Source	National weather department	Local government
levels	Rainstorm blue warning, rainstorm yellow warning, rainstorm orange warning, and rainstorm red warning	Ready-to-evacuate warning and immediate-evacuation warning
Communication characteristic	Wide	Precise
Communication means	SMS, Wechat, and internet	Whistle, gong, and broadcast

explore the effect of received warning type on people's EED, respondents were asked a set of questions to assess their evacuation intention receiving rainstorm red warning, ready-to-evacuate warning, and immediate-evacuation warning, respectively. Specifically, respondents were asked to express their willingness to evacuate in each warning scenario. Their responses were coded as a five-points scale from 1 ("totally unwilling") to 5 ("totally willing"). The three types of warnings indicated the sources of the warning message, thereby, eliminating the different interpretations of the information caused by different assumptions of the respondents about the source of the information.

4.3 Statistical analysis methods

An ordinal logistic regression model was used to analyze the independent influence of the personal factors on evacuation intention under the three flash flood characteristics. Logistic regression is taken as an extension of linear regression while ordinal logistic regression is regarded as a combination of multiple logistic regressions. The ordinal logistic regression equation is written as follows:

$$\log it = \log \frac{p(y \le j)}{1 - p(y \le j)} = \beta_{0,j} + x'\beta_j \quad j = 1, 2, 3, 4 \tag{1}$$

where $p(y \le j)$ is the probability that the dependent variable y (i.e., evacuation intention in this study) is less than or equal to j and j is 1–4 since the coding of evacuation intention was divided into 5 levels; $\beta_{0,j}$ is intercept term and β_j is a vector of regression coefficients; x' is a vector of explanatory variables (i.e., personal factors related to EED in this study).

A path analysis to test the causal flow from the personal factors to evacuation intention was used to analyze the influence process of the personal factors on evacuation intention under the three flash flood characteristics. In this study, the path analysis included a set of regression models that explained the variables in the extended PADM, a systematic multi-stage model. A detailed introduction on the extended PADM can be found in the Supplementary Note 1.

To tested the differences in the effect of received warning type on evacuation intention under the three flash flood characteristics, an ordinal logistic regression model was performed with evacuation intention as the dependent variable, warning type, region (i.e., a categorical variable for the three case study regions), and interaction term of warning type and region (i.e., warning type × region) as independent variables, controlling for socio-demographic characteristics. If the interaction term is significant, the effect of warning type on evacuation intention will be moderated by the flash flood characteristics. Hence, the effect of warning type on evacuation intention will be varied with flash flood characteristics.

5 Results and discussion

To explore the personal factors influencing EED under different flash flood characteristics, we analyzed the independent influence (Sect. 5.1) and influence process Sect. 5.2) of the personal factors on EED under different flash flood characteristics. The effect of received warning type on EED under different flash flood characteristics was specially analyzed (Sect. 5.3) as received warning type was one of the primary factors driving EED.

5.1 Independent influence of personal factors on EED under different flash flood characteristics

To analyze the independent influence of the six personal factors on EED under different flash flood characteristics, three ordinary logistical models were developed (see Table 7). For each personal factor, it had been figured out whether the independent influence of the personal factor on evacuation intention was varied with the flash flood characteristics.

The independent influence of flood experience on evacuation intention was firstly analyzed under different flash flood characteristics. Flood experience significantly and positively influenced evacuation intention in Liulin and Junchuan ($p < 0.05$), but not in Badou ($p > 0.05$). The independent influence of flood experience on evacuation intention was varied with the flash flood characteristics. It was in line with the previous results summarized in Sect. 2. As described in Sect. 3.2, the "8.12 event" caused significant losses in Liulin and Junchuan while "8.10 event" caused few losses in Badou. The people in Liulin and Junchuan had a profound loss experience while the experience in Badou was viewed as low risk. A profound loss experience rather than a hazard experience alone fosters the high-risk perception and risk avoidance behaviors (Perry and Lindell 1990; Riad et al. 1999). Therefore, the people in Liulin and Junchuan could attribute flash flood experience to evacuation intention while the people in Badou could not. Additionally, the flash floods in Liulin and Junchuan became more frequent after 2000, and there was a flash flood event that just occurred five months before our interview (conducted from January to March 2022) in the two towns as stated in Sects. 3.1 and 3.2. Therefore, people in Liulin and Junchuan could easily trigger their flood experiences for evacuation intention owing to their profound flood memories. And people in Badou could not easily trigger their flood experiences for evacuation intention because of their misty flash flood memories from low-frequency and distant flash floods (Kirstin et al. 2000).

Reliance on hazard information only significantly and positively influenced evacuation in Junchuan ($p < 0.01$). The independent influence of reliance on hazard information on evacuation intention was varied with the flash flood characteristics, which was consistent with the results in the literature review. Robert et al. (2010) has concluded that the effect of the degree of reliance on hazard information on EED was more prominent for people outside the evacuation zone than for people inside the evacuation zone. Although there was no officially designated evacuation zone in Liulin and Junchuan, the "8.12 event" made almost all people in Liulin evacuate, while people in Junchuan did not evacuate owing to the moderate severity of the "8.12 event" in their location. Therefore, reliance on hazard information had varying effects on evacuation intention under the three flash flood characteristics.

The p-values of perceived exposure greater than 0.05 in all the three towns meant that perceived exposure cannot influence evacuation intention regardless of the flash flood characteristics, which contradicted the results in the literature review. However, the perceived exposure was significantly correlated to evacuation intention according to our correlation analysis. There should be mediating ways between the perceived exposure and evacuation intention. Thus, a systematic path analysis would be adopted to examine the causal flow from the personal factors to evacuation intention in Sect. 5.2.

For risk perception, the fear of flash flood disasters increased evacuation intention in Junchuan ($p < 0.01$). In addition, if a person believed that he or she was safe to stay

Table 7 Results of ordinal logistic regression that predicts evacuation intention by the personal factors

Region	Liulin		Junchuan		Badou	
	Odds ratio	Standard error	Odds ratio	Standard error	Odds ratio	Standard error
Socio-demographic characteristics						
Age	0.84	0.48	1.14	0.19	1.18	0.14
Gender (reference = female)						
Male	1.72	0.45	1.10	0.19	0.84	0.20
Educational level	0.78	0.35	1.30*	0.12	1.10	0.12
Length of residency	0.97	0.18	0.88*	0.07	1.02	0.09
Floor	0.72	0.44	1.68**	0.18	1.29	0.20
Flood experience						
Own experience (reference = no)						
Yes	N/A	N/A	N/A	N/A	1.71	0.28
Other people's experience (reference = no)						
Yes	N/A	N/A	N/A	N/A	1.36	0.32
Previous loss	2.30*	0.33	1.26*	0.11	N/A	N/A
Reliance on hazard information	1.44	0.46	1.99**	0.21	0.97	0.12
Perceived exposure	0.97	0.37	1.07	0.08	0.92	0.11
Risk perception						
Perceived likelihood	1.50	0.44	1.01	0.16	0.91	0.14
Perceived severity	0.66	0.44	0.90	0.12	1.13	0.09
Worry	0.60	0.43	1.03	0.10	1.15	0.08
Fear	1.54	0.45	1.29**	0.09	1.04	0.08
Perceived home safety	0.32***	0.30	0.74**	0.10	0.73***	0.08
Responsibility	0.89	0.22	0.98	0.08	1.11	0.08
Warning type (reference = immediate-evacuation warning)						
Rainstorm red warning	0.01***	0.61	0.04***	0.29	0.03***	0.29

Table 7 (continued)

Region	Liulin		Junchuan		Badou	
	Odds ratio	Standard error	Odds ratio	Standard error	Odds ratio	Standard error
Ready-to-evacuate warning	0.06***	0.55	0.47**	0.22	0.33***	0.27
/cut1	N/A	N/A	0.09*	0.95	0.04***	0.90
/cut2	0.00**	3.11	0.62	0.89	0.08**	0.89
/cut3	0.00*	3.06	1.87	0.89	0.21	0.88
/cut4	0.15	3.00	21.71**	0.91	0.83	0.88
LR Chi2	114.98***	265.12***	229.26***			
Nagelkerke R^2	0.59	0.64	0.58			
N	54.00	98.00	98.00			

Italics represent the personal influencing factors being analyzed

*, **, and *** indicate significance at the 5%, 1%, and 0.1% levels, respectively. A personal factor is considered to have a significant impact on evacuation intention when the significance level is less than 5%. Odd ratios > 1.00 indicates that the increase of independent variable plays a positive role in increasing the odds (or likelihood) of evacuation intention. Odd ratios < 1.00 indicates that increase of independent variable plays a negative role in increasing the odds of evacuation intention. Odd ratios = 1.00 indicates the independent variable has no effects on the evacuation intention

Fig. 3 Results of the path analysis to test the causal flow from the personal factors to evacuation intention in Liulin **a**, Junchuan **b**, and Badou **c**. The numbers on the lines refer to regression coefficients. Only significant relationships are shown in arrows. *, **, and *** indicate significance at the 5%, 1%, and 0.1% levels, respectively ▶

at home during the flash flood disasters, he or she would be reluctant to evacuate in all the three towns ($p < 0.001$ in Liulin and Badou, and $p < 0.01$ in Junchuan). Thus, risk perception had a consistent positive influence on evacuation intention regardless of the flash flood characteristics.

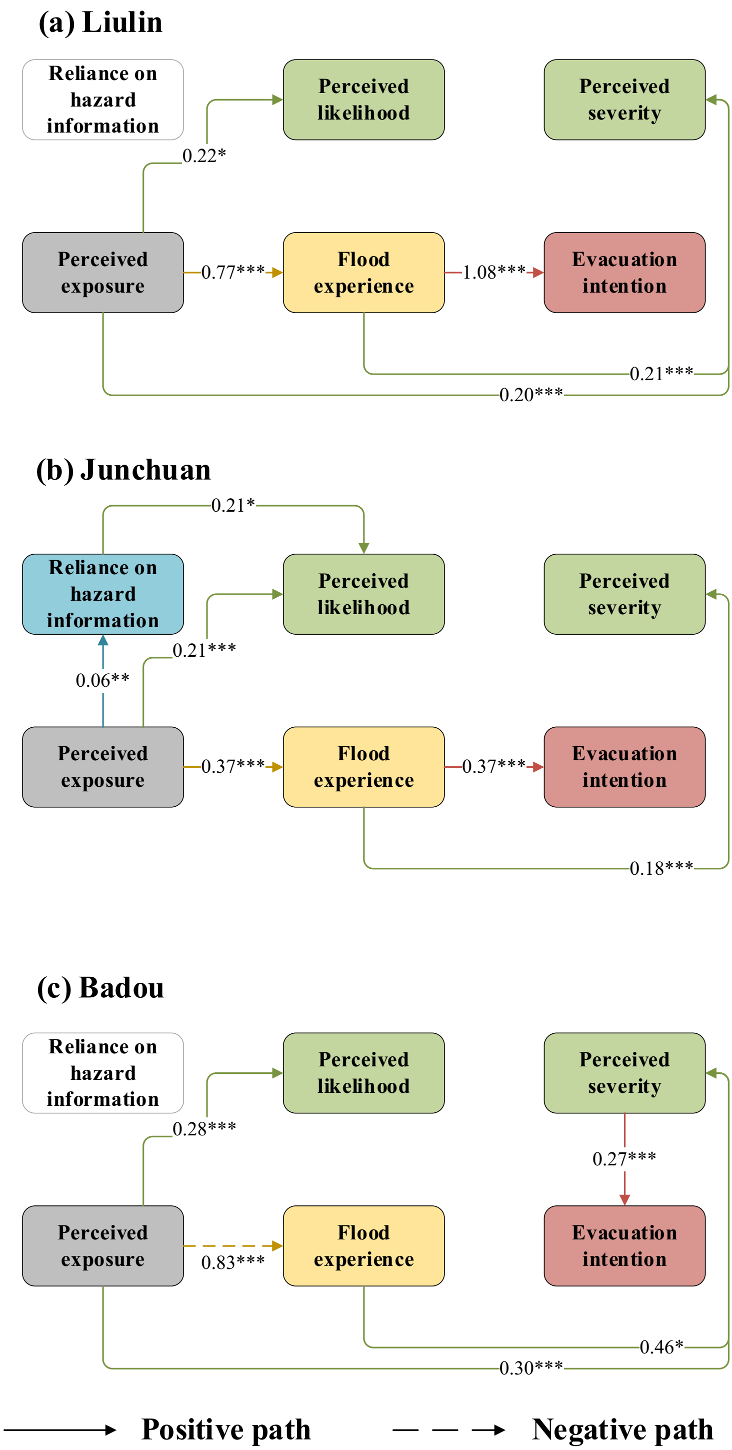
Finally, we analyzed the independent influence of responsibility and warning type on evacuation intention under different flash flood characteristics. The p-values of responsibility greater than 0.05 in all the three towns indicated that responsibility had limited effects on evacuation intention under the three flash flood characteristics. This result was consistent with the previous studies as mentioned in Sect. 2. For warning type, it was the strongest predictor of evacuation intention in all the three towns ($p < 0.001$). Mandatory warning (e.g., immediate-evacuation warning) was more likely to urge people to evacuate than suggestive warning (e.g., rainstorm red warning). Thus, warning type had a consistent and significant effect on evacuation intention regardless of the flash flood characteristics.

After analyzing the independent influence of the six personal factors on evacuation intention under different flash flood characteristics, the independent influence of socio-demographic characteristics on evacuation intention was also analyzed (see Table 7). The p-values of most socio-demographic characteristics greater than 0.05 in all the three towns indicated that most socio-demographic characteristics cannot influence evacuation intention regardless of the flash flood characteristics. This was in line with the previous studies that concluded socio-demographic characteristics were poor predictors of flood disaster prevention behaviors (Grothmann and Reusswig 2006; Zaalberg et al. 2009; Bubeck et al. 2012). Furthermore, it was interesting to find that people living on the second floor and above were more likely to evacuate than those living on the first floor in Junchuan ($p < 0.01$). This phenomenon had not be found in the other two towns. As the severity of the "8.12 event" was moderate and only able to cause property losses instead of life losses in Junchuan (see Sect. 3.2), the people living on the first floor in Junchuan protected their property rather than evacuating owing to the high exposure of their property. Thus, "8.12" event in Junchuan fostered a false judgement that they could handle another flash flood without evacuation. This phenomenon was attributed to the "false experience effects" (Baker 1991).

5.2 Influence process of personal factors on EED under different flash flood characteristics

To analyze the influence process of personal factors on EED under different flash flood characteristics, three causal flows from the personal factors to evacuation intention were conducted (see Fig. 3). In Fig. 3, only significant relationships were denoted by the arrows. Positive relationships were denoted by the solid lines while negative relationship was denoted by the dashed line. The numbers on the lines were the regression coefficients. The details of the path analysis results are provided in Tables S1-S3.

According to the causal flow shown in Fig. 3, the influence process of the personal factors on evacuation intention can be determined under different flash flood characteristics. Perceived exposure impacted flood experience, and then flood experience impacted


(a) Liulin
Reliance on hazard information
Perceived likelihood
Perceived severity
0.22*
Perceived exposure
0.77***
Flood experience
1.08***
Evacuation intention
0.21***
0.20***
(b) Junchuan
0.21*
Reliance on hazard information
Perceived likelihood
Perceived severity
0.21***
0.06**
Perceived exposure
0.37***
Flood experience
0.37***
Evacuation intention
0.18***
(c) Badou
Reliance on hazard information
Perceived likelihood
Perceived severity
0.28***
0.27***
Perceived exposure
0.83***
Flood experience
Evacuation intention
0.46*
0.30***
Positive path
Negative path

evacuation intention in Liulin and Juchuan, while perceived exposure impacted risk perception (i.e., perceived severity), and then risk perception impacted evacuation intention in Badou (see Fig. 3). Therefore, perceived exposure indirectly influenced evacuation intention through the mediation of other factors, but the mediating factors were varied with the flash flood characteristics. The high-frequency, recent, and loss-causing flash floods caused people to experience property and life losses, and brought a deep flood memory to people in Liulin and Junchuan. The loss experiences and their corresponding deep memories could result in consistent high-risk perception to people.[3] The low diversity in risk perception explained the insignificant effect of risk perception on evacuation intention in Liulin and Junchuan. However, risk perception was diverse[4] in Badou because there were low frequent, distant, and few-loss-causing flash floods in the region. The diverse risk perception explained evacuation intention in Badou.

The causal flow explained why the literature reviewed had found that perceived exposure could influence evacuation intention, but we had not in Sect. 5.1. Figure 3 showed that perceived exposure was actually relevant to evacuation intention through the mediation effect of risk perception or flood experience. However, the mediation effect of risk perception or flood experience was complete. The independent influence of perceived exposure on evacuation intention was no longer significant ($p > 0.05$) after controlling for risk perception and flood experience (see Table 7). The results also demonstrated that the causal flow can identify the factors that were not significantly related to the final decisions; nevertheless, it can influence the early process of the decisions.

Finally, an interesting finding was that that flood experience had a positive effect on perceived severity in Badou (see Fig. 3). Flood experience was measured as whether people had experienced a flash flood event or not (i.e., "yes" coded as 1 and "no" coded as 2). The positive relationship between flood experience and perceived severity meant if a person had experienced flash floods in Badou, s(he) would have lower perceived severity. This result was also supported by the "false experience effects".

5.3 Effect of received warning type on EED under different flash flood characteristics

To test the differences in the effect of received warning type on EED under different flash flood characteristics, an ordinal regression model was developed and its results were shown in Table 8. If there is a significant interaction between the explanatory variables, the flash flood characteristics moderate the effect of warning type on evacuation intention. Therefore, the effect of warning type on evacuation intention is varied with the flash flood characteristics.

As the p-values of the first two interaction terms (Liulin $_\times$ Rainstorm red warning and Junchuan $_\times$ Rainstorm red warning) were less than 0.001 (see Table 8), the effect of warning type on evacuation intention was varied with the flash flood characteristics when the warning type changed from the rainstorm red warning to ready-to-evacuate warning. The effect of warning type on evacuation intention could be classified into small, medium, and large in Liulin, Junchuan, and Badou, respectively. The mean evacuation intention value of residents in Badou was only 2.52 when there was a rainstorm red warning as shown in

[3] The coefficient of variation is 0.144 and 0.230 in Liulin and Junchuan, respectively.

[4] The coefficient of variation is 0.321 in Badou.

Table 8 Results of ordinal logistic regression that predicts evacuation intention by warning type, region, and their interaction terms

Explanatory variable	Odds ratio	Standard error
Socio-demographic characteristics		
Age	1.34*	0.14
Gender (reference = female)		
Male	0.71*	0.16
Educational level	1.00	0.10
Length of residency	0.94	0.06
Floor	1.31	0.15
Warning type (reference = immediate-evacuation warning)		
Rainstorm red warning	0.00***	0.36
Ready-to-evacuate warning	0.25***	0.32
Region (reference = Badou)		
Liulin	0.61	0.34
Junchuan	0.61	0.28
Liulin × Rainstorm red warning	22.46***	0.48
Junchuan × Rainstorm red warning	4.48***	0.39
Liulin × Immediate-evacuation warning	2.04	0.55
Junchuan × Immediate-evacuation warning	0.60	0.43
/cut1	0.00***	0.65
/cut2	0.01***	0.63
/cut3	0.03***	0.62
/cut4	0.59	0.60
LR Chi2	469.16***	
Nagelkerke R^2	0.50	
N	250.00	

Italics represent the personal influencing factors being analyzed

Fig. 4. When the warning type changed into the ready-to-evacuate warning, the mean evacuation intention value rapidly increased to 4.37. In contrast, the mean evacuation intention value of residents in Liulin was high regardless of the warning type (3.91 for rainstorm red warning and 4.28 for ready-to-evacuate warning).

As the p-values of the last two interaction terms (Liulin × Immediate-evacuation warning and Junchuan × Immediate-evacuation warning) were greater than 0.05, there was no significant difference in the effect of warning type on evacuation intention regardless of the flash flood characteristics when the warning type changed from the ready-to-evacuate to immediate-evacuation warning. When the warning type changed from the ready-to-evacuate to immediate-evacuation warning, the mean evacuation intention values slightly increased from 4.28 to 4.81, from 4.3 to 4.54, and from 4.37 to 4.74 in Liulin, Junchuan, and Badou, respectively (see Fig. 4).

5.4 Discussion

The independent influence of perceived risk perception and warning type on evacuation intention was consistent regardless of the flash flood characteristics, while the independent

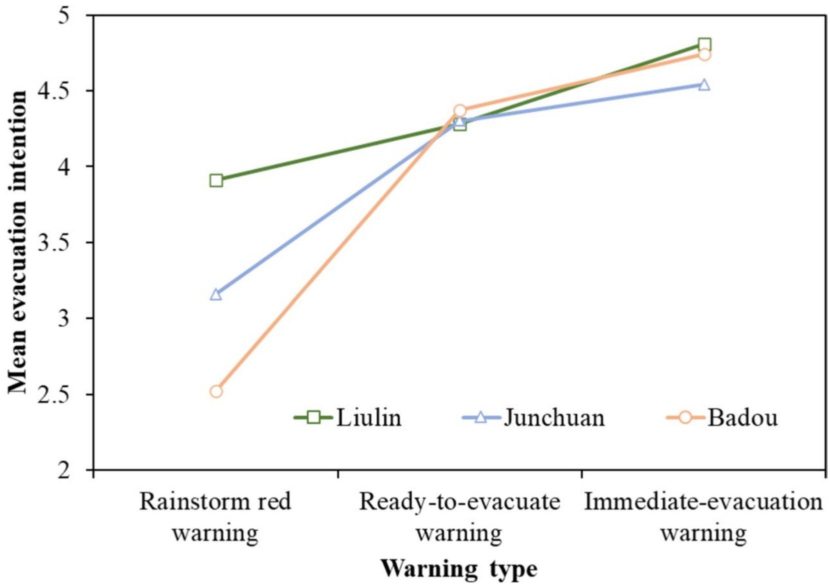


Fig. 4 Mean evacuation intention predicted by variable region and warning type

influence of flood experience and reliance on hazard information on evacuation intention was varied with the flash flood characteristics. Therefore, emergency administrators should carefully examine the personal factors and implement distinctive emergency management according to specific flash flood characteristics. For example, people living on the first floor were unwilling to evacuate after experiencing a low-severity flash flood. Emergency administrators need to provide special information to help the people objectively assess flash flood risk to eliminate biases brought by the "false experience effects".

The influence process of the personal factors on EED showed that the mediating factors between perceived exposure and evacuation intention were varied with the flash flood characteristics. When there were high-frequency, recent, and loss-causing flash floods, people would experience property or life losses with their deep flood memories, and thus easily relate flood experience to evacuation intention. Hence, flood experience was the mediating factor between perceived exposure and evacuation intention. When a loss experience or its memory was missing, risk perception became diversified and played a dominant role relative to experience, and was the mediating factor between perceived exposure and evacuation intention. Thus, risk communication has high marginal benefits when loss experiences and memories are missing. As suggested by Bradford et al. (2012), those who lack personal flash flood experience need more risk information. Emergency administrators should provide the targeted information to fill the gaps in their experiential learning.

When the warning type changed from the suggestive rainstorm red warning to mandatory ready-to-evacuate warning, the effect of warning type on evacuation intention were found to be varied with the flash flood characteristics. People in Badou were found to ignore the suggestive rainstorm red warning and rely on the mandatory ready-to-evacuate warning. Due to the low-frequency, distant, and few-loss-causing flash floods in Badou, almost all the residents have not experienced any property damage, and the memory of flash floods is vague. After receiving rainstorm red warning as a suggestive warning that only indicates flood risk, the insufficient intuitive understanding of flash flood disasters makes it difficult for them to interpret such risk. Moreover, as the rainstorm red warning is widely issued to public through the SMS, WeChat, and internet, the warning information is difficult to be linked with the local environment. The flash flood risk can be interpreted as unrelated to residents in Badou, resulting in low evacuation intention. After receiving ready-to-evacuate and immediate-evacuation warnings, people have high evacuation intention regardless of the flash flood characteristics. Because these warnings are mandatory, and local governments issue targeted warnings through whistle, gong, and broadcast, the main factors influencing evacuation intention are the authority and credibility of the local government. The high trust in local government determined the residents' responses to the two types of warnings issued by local government. As a result, the residents would follow the evacuation instructions of the government regardless of the flash flood characteristics.

However, the suggestive rainstorm red warning can help the evacuation. After receiving the suggestive MW, people can assess their current situation, pay close attention to the information, and even prepare for disaster to facilitate the final evacuation. Additionally, the release of ready-to-evacuate warning may be delayed or even be missing because of high uncertainty of FFDW resulted from the stochastic time and location of a flash flood (Collier 2007). Even if the flash floods are exactly predicted, many obstacles remain with respect to transmitting the warning information to the threatened individuals, such as the short flood warning lead times, the inefficiencies warning dissemination system, and the unavailability or inability to receive flood warnings (Parker et al. 2009). Therefore, it is vital to reduce reliance on FFDW and give more weight to MW, especially in the regions with low-frequency, distant, and few-loss-causing flash floods. The failure of the suggestive role of rainstorm red warning can be seen as an opportunity to enhance self-protection ability through improving the level of public responses to MW.

The context of a region (e.g., economy, information accessibility, education level, and culture) can interfere with the risk perception and acceptance of warnings, thereby affecting people's EED. For example, culture, as a shared belief, value system, and behavior norms of a society or group, profoundly shapes how people perceive natural disasters and how they respond to them. Specifically, agricultural societies may believe that floods bring fertile land and harvests, and therefore may have a positive attitude towards floods. And some religions consider floods as natural punishments or tests, so people face disasters with a submissive or fated attitude (Ha 2015). Furthermore, collective/individualistic culture and government authority can affect people's understanding of flood disasters and the interpretation of warning information (Mercer 2010; Yang et al. 2015). However, the three case study regions are all in the same country and belong to the same administrative level, so they do not differ on too many contextual factors. For example, the economy and education levels of these three regions are similar. The per capita GDP of Suixian County, where Liulin and Junchuan are located, and Boshan District, where Badou Town is located, are 6.7 thousand dollars and 9.7 thousand dollars, respectively. The coverage rates of nine-year compulsory education in Liulin, Junchuan, and Badou are 100%, 99%, and 100%, respectively. Therefore, there should not be significant differences among these three regions in disaster prevention infrastructure, emergency response capabilities, and information acquisition channels that can affect people's attitudes, concepts, and risk perception towards disasters.

It should be noted that there are differences in the economic types of these three regions. Compared to Badou, Liulin and Junchuan rely more on agricultural economy and less on industrial economy. The total agricultural production value of Liulin and Junchuan is 122.8 million dollars and 32.5 million dollars respectively, while that of Badou is only 11.3

million dollars. As for large and medium-sized industrial enterprises, there are 8, 13, and 83 in Liulin, Junchuan, and Badou, respectively. Due to the fact that agriculture is usually more susceptible to severe impacts of floods than industry, and the recovery time and cost of agriculture are usually higher, the difference in economic types may interfere with risk perception and the acceptance of warnings, thereby affecting people's EED (Bubeck et al. 2012; Winsemius et al. 2016).

Contextualizing the study area from the perspectives of flash flood characteristics and social conditions helps to gain a broad understanding of the personal factors influencing the EED. The globally gridded socio-economic dataset provides a feasible path for contextualizing large-scale regions. In further studies, it is possible to explore the use of these global datasets to establish connections between regional socio-economic and environmental conditions and the personal factors influencing EED, in order to obtain more general conclusions.

As the interviewees were selected through convenient sampling, the sample should not be considered to be fully representative of the overall population. For example, our sample contained more women in Junchuan and few older adults. Weighting technology was used to match gender to the known population profile. However, the weighting technology limited the application in other demographic attributes because the data related to the attributes referring to the personal privacy and was difficult to obtain. It should be kept in mind that our results were not applicable to the responses of the elderly people, and more elderly people sample should be taken into account in future work.

EED were measured by self-reported evacuation intention in scenarios rather than the actual behaviors in real world. If a person has high evacuation intention, we cannot assure that he or she will evacuate successfully in case of a real flash flood owing to complex and uncertain realities. For example, the elder people were more willing to evacuate in our survey, but they prefer to stay at home in reality due to their capability limitations. However, our study can help people understand and apply EED in reality, because there is a similarity between the effect size of factors examined in self-reported evacuation intention and actual evacuation (Huang et al. 2016).

It is important to know how the received flash flood disaster warning is interpreted and responded to in a social context. Generally, people who have received a warning tend to discuss and confirm the information with their family, friends, neighbors, or coworkers, and even just follow behaviors of others without their own considerations. Besides disaster warnings, people receive multiple pieces of disaster information from a variety of sources. Thus, the effect of disaster warnings can be influenced by the social context. However, the data statistics paradigm adopted in our study has not taken the social context into account. Owing to the complex and dynamic interaction and verification process of disaster information, an analogue simulation paradigm (e.g., agent-based modelling) is recommended for further research.

Although some personal factors related to EED have been discussed based on PADM, many other factors have not been considered. For example, the coping appraisal process has been used for assessing the ability, effectiveness, and cost to implement protective measures, and it is usually found to be a significant determinant of protective behaviors for the flood disasters (Grothmann and Reusswig 2006). If the threat appraisal is high but coping appraisal is low, a person will take non-protective responses including threat denial, wishful thinking, and fatalism (Grothmann and Reusswig 2006). Future research can develop a hybrid framework that couples multiple theories to fully understand EED and conduct systematic comparisons of these theories to identify the most appropriate theory to explain EED.

6 Conclusions

Personal factors influencing EED have been explored under different flash flood characteristics (i.e., the frequency, occurrence time, and severity of flash floods) through field survey data. Three typical flash flood characteristics in three towns were selected as case studies. We analyzed the independent influence and influence process of the personal factors on EED, and the effect of received warning type on EED under the three flash flood characteristics. The specific findings were summarized as follows.

Personalized risk perception and warning type consistently influenced evacuation intention regardless of the flash flood characteristics, while the independent influence of flood experience and reliance on hazard information on evacuation intention was varied with the flash flood characteristics. Emergency administrators should carefully examine the personal factors related to EED and implement distinctive emergency management according to specific flash flood characteristics. Particularly, the low evacuation intention of people on the first floor in Junchuan indicates that it is necessary to specially communication risk to these people to eliminate the “false experience effects”.

From the perspective of the causal flow, perceived exposure influenced evacuation intention through the mediations of flood experience when there were high-frequency, recent, and loss-causing flash floods, and of risk perception when there were low-frequency, distant, and few-loss-causing flash floods. Therefore, emergency administrators are recommended to allocate more resources to improve risk perception in regions with low-frequency, distant, and few-loss-causing flash floods for high marginal benefits.

When the warning type changed from the suggestive rainstorm red warning to mandatory ready-to-evacuate warning, the effect of warning type on evacuation intention were found to be varied with the flash flood characteristics. When the warning type changed from the ready-to-evacuate to immediate-evacuation warning, there was no significant difference in this effect regardless of the flash flood characteristics. Particularly, people from the regions with low-frequency, distant, and few-loss-causing flash floods, such as Badou, tended to ignore suggestive MW and were dependent on mandatory FFDW. Therefore, emergency administrators can help them develop proper knowledge regarding the warning types to reasonably make EED.

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Author Contributions All authors contributed to the study conception and design. Conceptualization, methodology, validation, investigation, formal analysis, data curation, and writing-original draft were performed by Ruikang Zhang. Conceptualization, methodology, writing—review & editing, supervision, and funding acquisition were performed by Dedi Liu. Validation, resources, writing—review & editing, and supervision were performed by Yongxin Xu. Conceptualization, writing—review & editing, and supervision were performed by Changjiang Xu. Conceptualization, writing—review & editing, and supervision were performed by Xi Chen. All authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Informed consent All interviewees were informed and agreed to participate in the research.

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