Research on User Experience Design of Public Warning System: A Case Study of Earthquake Alert of Mobile Device

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Abstract

The earthquake alert is a warning message the public will receive when an earthquake occurs in Taiwan. Although the information distribution unit is the central government, the core of the construction lacks a user perspective. Through affinity mapping of user experience investigation, it is found that most users want to receive information about "main earthquake," "warning type," "extended disaster," "refuge instruction," "post-earthquake related information," and "status report." Next, the three designers are asked to follow the above information requirements and design earthquake alert interfaces. Thirdly, the interface will be adjusted after expert interviews, interface evaluation feedback, and testing. Finally, the formal test passed the usability test of 35 participants. The research concluded that the information content could be divided into three types: "disaster information," "user guidance," and "the subsequent current situation and others" and found that the information process should be divided into (1) before and during the earthquake (2) the first half of the earthquake (3) the second half of the earthquake (4) the second half of the earthquake. This study has summarized seven critical points of the design interface, including (1) simple and straightforward important text, (2) color discrimination of earthquake levels, (3) simple images related to information transmission, (4) enlargement of important text and images in crises (5) page flashing display can improve the attractiveness to users (6) the design of buttons should have guiding functions (7) complex information can be simplified through links to reduce the burden of users.

Keywords: Earthquake Alert, Earthquake Warning Page, User Interface, User Experience, Usability, Affinity Diagram

1. Introduction

Each country has its corresponding measures to address the threat of earthquake disasters. The government provides the earthquake information, the earthquake app, or the device's built-in system so that the public (users) can quickly understand the situation and respond to actions in the face of an earthquake. However, the stressful environment will damage users' information processing ability during a disaster (Stratmann & Boll, 2016). In addition, in the face of such crises as earthquakes, the development of uncertainty in disasters, rapid response actions, and inappropriate actions that cause loss of life and property are often accompanied (Yang, Yang& Plotnick, 2013). Therefore, the disaster-type system's quick earthquake reports design should be based on users. Otherwise, it will cause trouble for users (Tan et al., 2020).

In Taiwan, the government is mainly forced to send earthquake alerts to public action devices as warning messages. Still, the earthquake alert is not created from the user's opinion, and the contents are displayed in plain text. And the built-in system of the disaster prevention brief report app, Google Alert, and Japanese Yahoo! use images to display earthquake information and prompt users to refuge actions. Graphics has become the main body of human-computer interaction in the era of intelligent data. Therefore, this study takes the Taiwan earthquake brief report as the design background and considers that the user uses the device under high risk (Sarshar, Nunavath & Radianti, 2015), providing critical, complete information. Necessary, updated information during the crisis (Harris, 2017) uses the seismic information expected by the user to design the page and finally proposes a new earthquake quick report interface design after passing the usability test. Therefore, the following three questions are raised:

1. What important information do users want to receive from the earthquake warning page when an earthquake occurs?
2. What is the user's use history of the earthquake warning page on the mobile device during the evacuation process?
3. What should be included in the interface design points of the earthquake warning page for users?

2. Literature Review

2.1 Earthquake alert message

When the seismic station near the earthquake's epicenter observes a shallow quake of medium and large scale (more than 4.5) has occurred. It happened on Taiwan islands or offshore areas; the positioning can be completed in 10 to 15 seconds. The time of occurrence, the epicenter's location, the focal point's depth, the earthquake's scale, and the earthquake's size can be obtained (Central weather bureau, 2018). The real-time warning of strong earthquakes means that after an earthquake occurs, before the arrival of destructive seismic waves (S waves) in various regions, the estimated arrival time, and the impact (earthquake intensity) of the S waves from multiple areas will be warned. If the alarm is issued before the arrival of the seismic wave, we can strive for several seconds to ten seconds of early warning (Central weather bureau, 2018). When the scale of the earthquake reaches more than 5.0, and the estimated intensity scale of the earthquake in which any county or city government is located reaches more than intensity scale 4 (intensity scale 3 in Taipei), the earthquake quick report message of strong earthquake instant warning will be released through the public warning system (PWS) to the mobile phones of the citizens in the county (Taiwan Inc., 2016). The end user will receive the earthquake quick report information displayed in the text, which includes the time of the earthquake, the location of the epicenter, the significant earthquake, the earthquake evacuation action, and the warning words "drop, cover, and hold" (Fig. 1).

Figure 1: 2022 latest earthquake alert mobile message (Ciou, 2022).

In an earthquake, the mobile phone will also emit sound and vibration. According to the third-generation mobile communication terminal's technical specification (National Communications Commission, 2018), the alarm sound and vibration signal can only be used in the disaster prevention alarm cell broadcast message. They cannot be synchronized with each other, nor can they be set and modified by themselves. The alarm sound is mainly composed of 853hz and 960hz of exceptional audio, and the alarm sound and vibration signal have a particular interval form (Fig. 2).

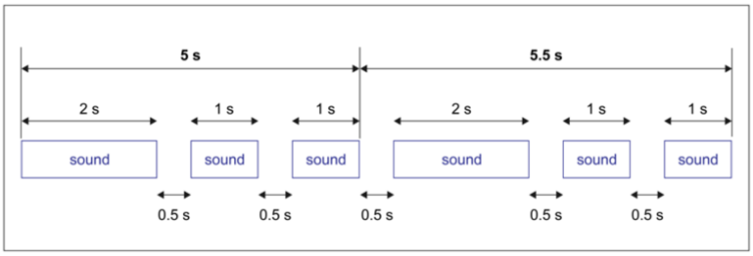

Figure 2: Special interval of alarm sound and vibration signal.

At present, because domestic people are still in the 3G/4G wireless communication environment, and due to factors, such as network stability, hardware performance of handheld devices, wireless push technology, application software development, etc., only fixed earthquake quick report messages can be provided with limited text warnings (Central weather bureau, 2018), however, with the enhancement of 5G technology, more changes can be made to the layout and design of the transmission of earthquake alert messages.

2.2 Earthquake warning page

Facing the threat of earthquake disasters, each country has its corresponding measures. In addition to the earthquake quick report messages sent by the government, there are even some apps that provide earthquake-related information or built-in earthquake warning systems, which enable users to receive nonpure text warning information in the face of earthquake conditions, and have more detailed content, so that users can more quickly interpret and understand the data and improve their self-protection awareness and response. The following will be a further analysis of the earthquake warning pages that jump out of various mobile device apps or built-in systems of an earthquake (Fig. 3).

According to the analysis of the earthquake warning pages of the above devices, it can be found that the information content and version provided by each carrier are different from each other, and the user must select a suitable warning page through multi-party comparison and selection. However, it cannot be directly compared with the general situation in the face of disasters. Users are likely to use it under extremely high-risk conditions (Sarshar, Nunavath & Radianti, 2015). Users' ideas in producing disaster-type products or early warning information must be paid more attention to. If designers or creators only assume and design according to their views, it is likely to hurt users in the event of disasters and thus endanger the personal safety of users.

Figure 3. Example of an earthquake warning page of a mobile device application or built-in system (Chen,2019;9M87,2018; University of California,2019; Yahoo! Japan, 2018; Hongyu and Bianji, 2019; Fakhrudin, 2021).

2.3 User experience design

User experience is only a sub-item of experience, focusing on a specific medium, interactive products (Hassenzahl, et al., 2013). When the situation involves the experience design, it is the question of consciously creating and shaping the experience. The experience is usually caused by direct observation or event participation, and the experience itself is an individual event responding to stimuli (Schmitt, 1999). To create a meaningful user experience, user experience design must be incorporated into the development of the organizational system process, and more attention can be paid to end users and their needs (Erdős, 2019).

Facing the current situation during the disaster, Prasanna and Huggins pointed out that the information system to assist the emergency may save lives and minimize economic losses. When ordinary users use emergency response technology, their behavior may differ from general fields. For the quick earthquake report information system, this environmental disaster management tool aims to enable technology to help users make immediate response measures in an emergency (Prasanna & Huggins, 2016).

Well-designed technology systems can help users make wise decisions in times of crisis. Still, if technologies are not designed according to the end users' situation, they will also hinder users (Tan et al., 2020). The emergency response system must focus on the design of human information processing processes and information systems to keep human cognition in the best state (Hiltz, Van de Walle & Turoff, 2014).

Faced with the occurrence of this type of immediate disaster, Abdelouhab, Idough, and Kolski pointed out that the goal should be set with the end user because the user-centered design method is more suitable for the early stage of the development process, and the participation of the end user is essential (Abdelouhab, Idoughi& Kolski, 2014). Design thinking (DT), which takes "user-centered design" as the core concept, also continues to emphasize that since the user of the product is the user himself, the essential participant in the design stage is the user (de Paula, Menezes& Araújo, 2014). It can be seen from this that if the design is not aimed at the user's needs, the product used at this time cannot let the user understand its content or use mode in the shortest time, or even misleading, which may turn the product's functionality into a threat and directly cause extremely high threat and harm to life safety.

3. Method and Materials

The experiment first uses Affinity Diagram to investigate the users' needs for the information content and process they want to receive during the earthquake. Collect the obtained data, and analyze the similarities or similarities proposed by the experimental groups in the experimental stage. By integrating the data of the affinity mapping method, we can improve and get the ideas and needs of users. These data can be used as the core basis for the design of earthquake warning pages under earthquake disasters (including "interface process," "customer journey map," "personas," and "situational assumptions") and become the design direction that designers need to follow in the focus body method. The designer will use Figma, the collaborative interface design software, to create the prototype design of the earthquake warning page, and the prototype design will be transformed into an interactive mode. In the expert and user interface pre-test, the iPhone with a 6.1-inch screen will play and operate the interface prototype. The interface's deficiencies created by the designer will be modified through the interview feedback results to optimize the overall interface.

Based on the modified interface, the participants will be tested through the interface operation under three situation simulations: (1) only the earthquake occurs; (2) the earthquake occurs first, and then the aftershock occurs; (3) the earthquake occurs first, and then the aftershock occurs, and finally, the shelter is opened. The first two situation simulations only have a simple interface jump; the participants do not need to operate the interface. The third scenario requires participants to use the interface and participate in the task test because the shelter's opening is a notification of the message and a guidance function. The execution of the task can help researchers understand the performance of the participants' interface operation time in the study of opening the shelter.

After the experiment, fill in three questionnaires: (1) System usability scale (SUS): 5-point scale (from 1 significantly disagree to 5 very agree), a total of 10 questions; (2) User interaction satisfaction questionnaire (QUIS): 10 point scale (from 0 very dissatisfied to 9 very satisfied), a total of 23 questions; (3) Interface perception questionnaire: 10 point scale (10 point scale, each group's opposite feelings are at both ends of the scale), four groups of feeling degree (relaxation vigilance, relief tension, security danger, fearlessness fear) ask questions on nine pages respectively, with a total of 36 questions. The experiment results were analyzed by SPSS software on the system usability scale (SUS), user interaction satisfaction questionnaire (QUIS), the problem of interface feeling, and the task operation time performance of participants. The issue of interface feeling was derived from the feedback induction of the participants in the pretest experiment.

4. Result and Analyses

According to the Affinity Diagram, most of the participants think the information of "the number of earthquakes in the receiver's location," "the location of the earthquake epicenter, " "earthquake evacuation action," "earthquake scale," "earthquake occurrence time," and "the nearest shelter" should appear during the earthquake process, and "mandatory display" is required when necessary. However, some information is not presented in the current earthquake alert messages, and the warning and guiding information should extend from before to after the earthquake. Based on the Affinity Diagram of the message summarization, the designer focus group method, and the preliminary test, the formal interface design drawing of the earthquake warning page is shown in Fig. 4.

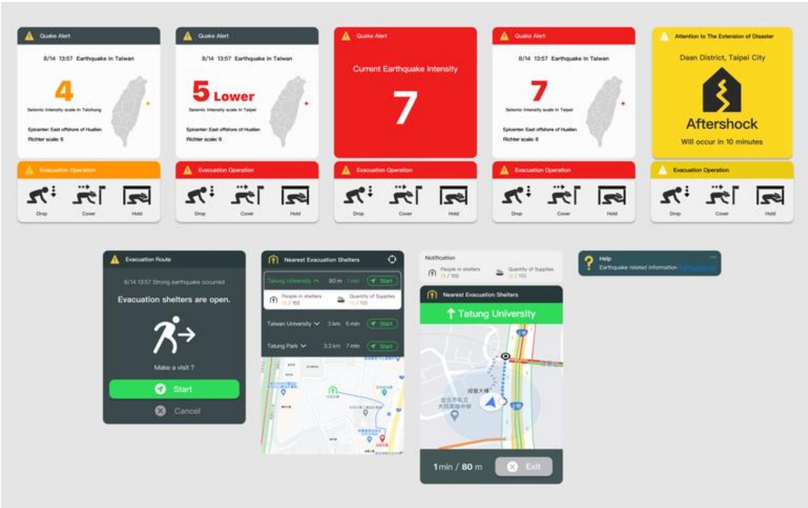

Figure 4: Earthquake warning page design.

According to Nunnally and Bernstein (1978), a Cronbach's alpha coefficient > 0.7 is considered high reliability, and the Cronbach's alpha coefficients of the three questionnaires were all greater than 0.7 (as shown in Table 1), so the questionnaire in this study has good internal consistency.

Table 1. Cronbach's alpha coefficient for each questionnaire.

Questionnaire	Question	Cronbach'sα
SUS	10	0.780
QUIS	24	0.922
Interface perception	36	0.927

4.1 System Usability Scale (SUS)

The total ease of use scores of 35 participants was higher than the standard average score of 68 points on the system ease of use scale, and the total average score was 88.1 point. Under 5 is the maximum score, and the average score of each question is higher than 4 points. SUS 8, 4, and 2 were the reverse questions expressing their disagreement. The questions issues all think they are ordinary or agree (Table 2).

Table 2. Descriptive statistics of system usability scale

No.	Question	Mean
SUS 10:	I needed to learn a lot of things before I could get going with this system. (disagreement)	4.77
SUS 8:	I found the system very cumbersome to use. (disagreement)	4.69
SUS 7:	I would imagine that most people would learn to use this system very quickly.	4.66
SUS 1:	I think that I would like to use this system frequently.	4.66
SUS 6:	I thought there was too much inconsistency in this system.	4.51
SUS 3:	I thought the system was easy to use.	4.51
SUS 9:	I felt very confident using the system.	4.46
SUS 5:	I found the various functions in this system were well integrated.	4.43
SUS 4:	I think that I would need the support of a technical person to be able to use this system. (disagreement)	4.29
SUS 2:	I found the system unnecessarily complex. (disagreement)	4.29

Score interval	Number of people (N=35)	Percentage (%)
70-79	9	25.7
80-89	8	22.9
90-100	18	51.4
Total average of scores：88.1		

4.2 User Interaction Satisfaction Questionnaire (QUIS)

According to the user interaction satisfaction questionnaire score, 9 is the maximum score for each question, the total score of the 35 participants was 216, and the total score of the questionnaire got 198.3. Table 3 shows the results of the questionnaire.

Table 3. A score on the system usability scale of the participants.

No.	Question	Mean
QUIS 4-1	Learn to operate the system (difficult - easy)	8.74
QUIS 4-3	Tasks can be performed easily and quickly (never - always)	8.54
QUIS 6-4	System and system interface (clutter-clear)	8.51
QUIS 5-3	Consider the needs of experienced and inexperienced users (never - always)	8.49
QUIS 3-3	The message provided on the interface (confusing - clear)	8.49
QUIS 4-2	Remember the name and function of the operation command (difficult - easy)	8.46
QUIS 3-4	Systematically lets you know what you're doing (never - always)	8.46
QUIS 3-2	Position of information in the interface (inconsistent - consistent)	8.43
QUIS 3-1	System terminology (inconsistent - consistent)	8.43
QUIS 6-3	System information and reports (shoddy - quality)	8.40
QUIS 5-1	Execution speed (very slow - fast enough)	8.29
QUIS 2-3	Information layout on the interface (Confused - Clear)	8.26
QUIS 2-1	The fonts displayed on the interface (Not easy to read - easy to read)	8.23
QUIS 2-4	Consistency of interface design (Confused - Clear)	8.23
QUIS 2-2	Marking of highlighting function (Useless - Useful)	8.23
QUIS 5-2	System reliability (unreliable - reliable)	8.23
QUIS 1-2	The overall response to the system (Simple - Difficult)	8.20
QUIS 6-1	The use of color and sound (shoddy - quality)	8.17
QUIS 1-3	The overall response to the system (Low performance - High performance)	8.14
QUIS 1-1	The overall response to the system (bad-good)	8.11
QUIS 6-2	System feedback (shoddy - quality)	7.94
QUIS 1-5	The overall response to the system (Inflexible - Flexible)	7.80
QUIS 1-4	The overall response to the system (Uninteresting - Interesting)	7.57

Score interval	Number of people (N=35)	Percentage (%)
150-159	1	2.9
160-169	1	2.9
170-179	2	5.7
180-189	2	5.7

190-199	11	31.4
200-209	10	28.6
210-216	8	22.9
Total average of scores：198.3		

4.3 Subjective Feelings of Interface

The total average of the four items (A sense of relaxation–alertness; Relief–Tension; Security–Danger; Fearlessness-Fear) in the questionnaire of the subjects' interface perception is shown in Table 4 and Fig.5. From interface 1 to interface 3.1, the subjects' average perception of each item gradually increases. The "sense of relaxation - a sense of vigilance" increased from an average of 6.1 to 8.7, tending progressively to the sense of vigilance. "Ease - tension" increased from an average of 5.6 to 8.7 and progressively became tense. The "sense of security - a sense of danger" increased from an average of 5.6 to 8.3, gradually tending to a sense of danger. "Fearlessness - fear" increased from an average of 5.1 to 8.2 and progressively grew to fear.

Table 4. A score on the system usability scale of the participants.

Interface (10-point scale)	A sense of relaxation - alertness	Relief–Tension	Security–Danger	Fearlessness-Fear
Interface 1	6.1	5.6	5.6	5.1
Interface 2	7.3	7.3	7.4	6.9
Interface 3.1	8.7	8.7	8.3	8.2
Interface 3.2	7.8	7.6	7.5	7.3
Interface 4	6.4	6	5.9	5.3
Interface 5	4.9	4.8	4.1	4.1
Interface 6	4.7	4.4	3.5	3.7
Interface 7	4.1	3.8	3.3	3.3
Interface 8	2.6	2.6	2.9	2.5

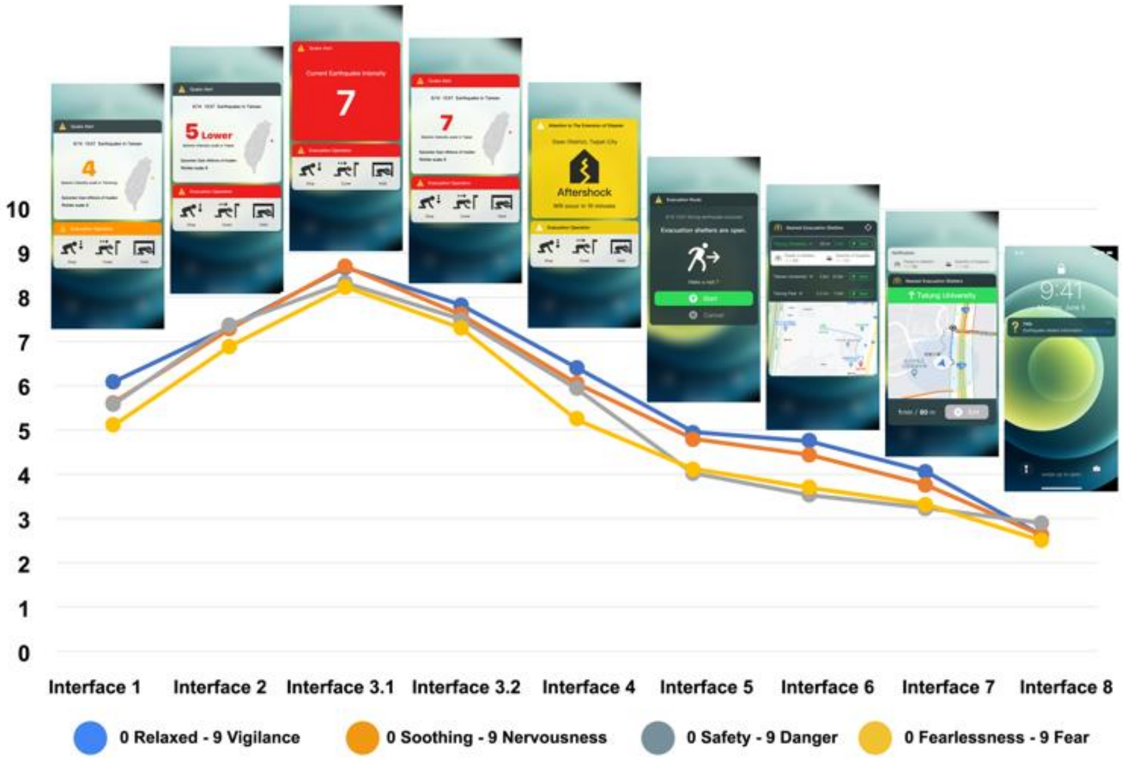

Figure 5: Average curve of the questionnaire for the degree of feeling of each interface.

From interface 3.2 to interface 8, the average feeling of the subjects in each item gradually decreased. "Sense of relaxation - a sense of vigilance" fell from 7.8 to an average of 2.6 and progressively tended to feel relaxed. "Sense of relief - a sense of tension" decreased from 7.6 to an average of 2.6, gradually growing to a sense of relief. "Sense of security - a sense of danger" decreased from an average of 7.5 to an average of 2.9, and gradually tended to feel safe. "Fearlessness - fear" fell from 7.3 to an average of 2.5 and progressively became fearless.

4.4 Discussion

After the formal experiment of the interface evaluation, the final proposal for the design of the earthquake warning page through the usability evaluation is obtained (Fig. 6).

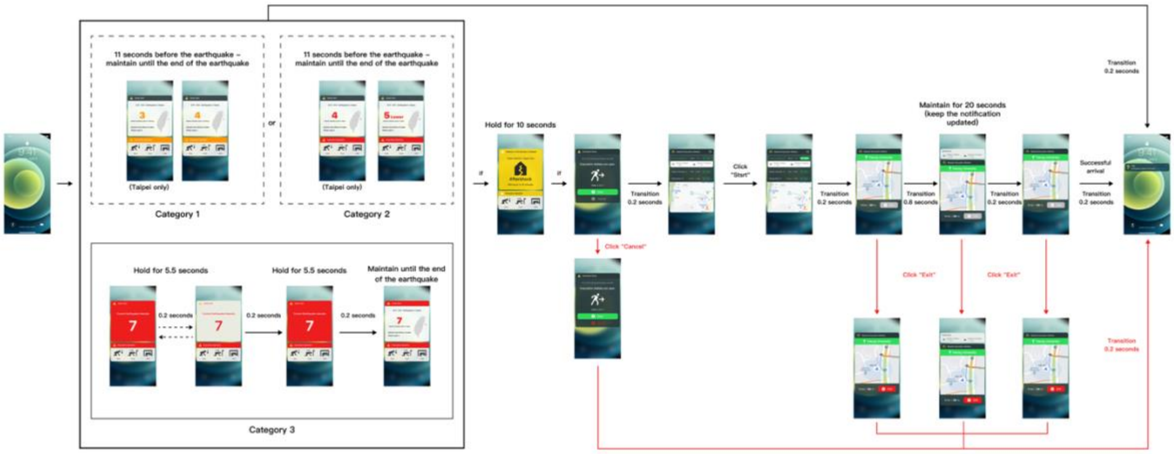

Figure 6. The interface of the earthquake warning page interactive use process final design.

The messages users want to receive on the earthquake warning page extend from before to after the earthquake and must be updated constantly. Most of the information is related to the main quake, and the comprehensive disaster information caused by the earthquake also attracts users' attention. This type of information content is related to "disaster information." Moreover, the information received about the evacuation action and instruction is associated with the safety and maintenance of the user's life. The user needs to receive relevant information on how to protect himself in a crisis, and the content of this information is related to the "user himself." The expectation of receiving relevant information after the earthquake and the status report with the family is associated with the information connectivity between the user and the current situation and the family. Such information belongs to the information linkage of "follow-up status and others."

In the early stage after the quake, users are most likely to face a second disaster caused by the extended disaster, so they need to receive information about the comprehensive disaster and self-protection again. In the next step after the catastrophe, users need relevant information about extending their safety to extend their lives. Finally, when the user is safe, he can learn more about the post-disaster situation and contact his family. Therefore, the information display process of the earthquake warning page should be divided into four stages, which are "before and during the earthquake," "the first part after the earthquake," "the middle part after the earthquake," and "the final part after the earthquake" (Fig. 7). The information that "must be displayed" in the information flow is "before and during the earthquake" and " the final part after the earthquake." Since the announcement of "the first part after the earthquake" and " the middle part after the earthquake " may not occur, these two kinds of information belong to "specific display" information. They will only appear in the process if they happen.

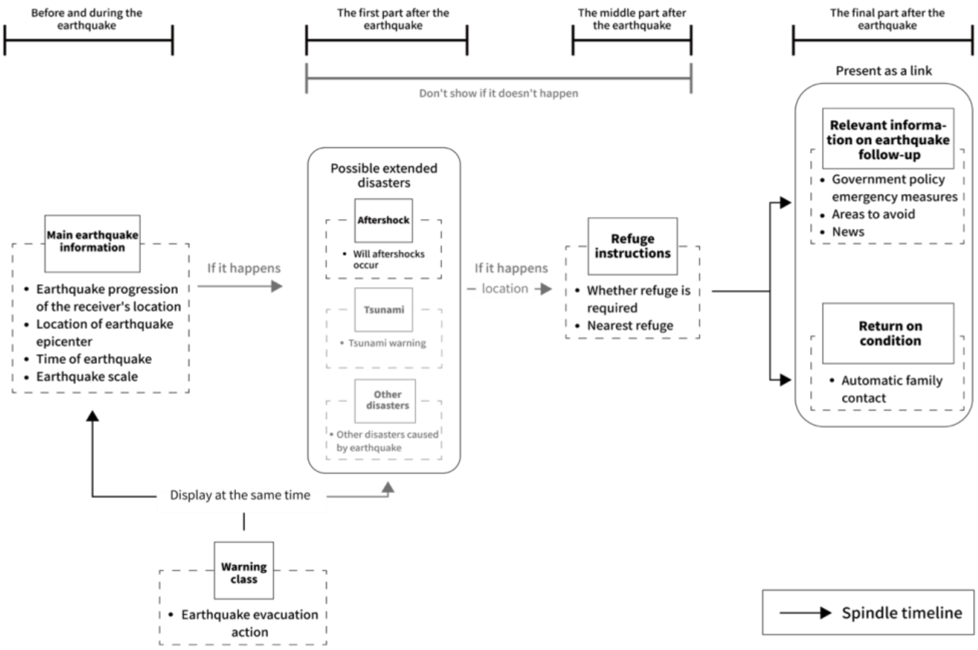

Figure 7. Earthquake warning page information display process.

In addition, the overall interface design is summarized in the following points. (1) All seismic stage designs should include simple but essential text information. (2) The use of color can be distinguished according to the earthquake level. (3) Using images related to the information conveyed on the page can also increase readability. (4) To reduce the reading burden of users in emergencies, the text or image can be enlarged in the design so that the information can be quickly conveyed. (5) The scintillation display used in this study shows that the interface with a design earthquake level more significant than five can attract users. (6) The button shall be designed to guide the user quickly in case of evacuation instruction. (7) The link design needs to appear in a safe state for users to choose to learn more.

5. Conclusion

The conclusion of this study was as follows:

1. The research concluded that the information content could be divided into three types: "disaster information," "user guidance," and "the subsequent current situation and others" and found that the information process should be divided into (1) before and during the earthquake (2) the first half of the earthquake (3) the second half of the earthquake (4) the second half of the earthquake.

2. This study has summarized seven critical points of the design interface, including (1) simple and straightforward important text, (2) color discrimination of earthquake levels, (3) simple images related to information transmission, (4) enlargement of important text and images in crises (5) page flashing display can improve the attractiveness to users (6) the design of buttons should have guiding functions (7) complex information can be simplified through links to reduce the burden of users.

3. The earthquake warning page information display process, interactive mode, and interface design system were proposed. In particular, the design of the entire system has been evaluated for usability, satisfaction, and user experience and has received high

comments. It can be used as a design reference for future research and can be used in practice.

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References

Abdelouhab, K. A., Idoughi, D., & Kolski, C. (2014, March). Agile & user centric SOA based service design framework applied in disaster management. In *2014 1st International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)* (pp. 1-8). IEEE. https://hal-uphf.archives-ouvertes.fr/hal-03383975

Chen, W. T. (2019, March 13). *Level 2 Earthquake Issued a National Alert Meteorological Bureau: The Depth of the Earthquake Leads to the Judgment Gap.* Central News Agency. https://www.cna.com.tw/news/firstnews/201903130058.aspx

Ciou, Y. Y. (2022, March 23). *The Cattle in the Middle of the Night Are Not Calm! Hualien Offshore 6.6 Magnitude Earthquake.* Yahoo! News. Retrieved August 8, 2022, from https://reurl.cc/Zrm5YM

Central weather bureau. (2018). *What Are the Methods and Channels of the Central Weather Bureau's Strong Earthquake Real-Time Warning to the Outside World? What Is the Future Development Plan?* Retrieved August 8, 2022, from https://scweb.cwb.gov.tw/zh-TW/Guidance/FAQdetail/100

Central weather bureau. (2018). *The Principle of Earthquake Early Warning*. Retrieved August 8, 2022, from https://scweb.cwb.gov.tw/zh-tw/guidance/eew/3

de Paula, D. F., Menezes, B. H., & Araújo, C. C. (2014). Building a quality mobile application: A user-centered study focusing on design thinking, user experience and usability. In *Design, User Experience, and Usability. User Experience Design for Diverse Interaction Platforms and Environments: Third International Conference, DUXU 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part II 3* (pp. 313-322). Springer International Publishing.

Erdős, F. (2019, October). Economical aspects of UX design and development. In *2019 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)* (pp. 211-214). IEEE.

Fakhrudin, A. (2021, June 18). *Fitur Baru Google "Android Earthquake Alert System*." Retrieved July 25, 2022, from https://javatekno.co.id/news/fitur-baru-google-android-earthquake-alert-system

Hassenzahl, M., Eckoldt, K., Diefenbach, S., Laschke, M., Lenz, E., & Kim, J. (2013). Designing moments of meaning and pleasure. Experience design and happiness. *International journal of design*, *7*(3), 21-31.

Harris, D. (2017). *Engineering Psychology and Cognitive Ergonomics: Cognition and Design: 14th International Conference, EPCE 2017, Held as Part of HCI International 2017, Vancouver, BC, Canada, July 9-14, 2017, Proceedings, Part II* (1st ed.). Springer Cham. https://doi.org/https://doi.org/10.1007/978-3-319-58475-1

Hiltz, S. R., Van de Walle, B., & Turoff, M. (2014). The domain of emergency management information. In *Information systems for emergency management* (pp. 15-32). Routledge.

Hongyu, & Bianji. (2019, November 20). W*orld's first pre-installed earthquake warning system released in Chengdu*. Retrieved July 25, 2022, from http://en.people.cn/n3/2019/1120/c90000-9634074.html

National Communications Commission (2018). *Technical specification for the third-generation mobile communication terminal equipment*. Taiwan standard. PLMN08. Retrieved August 8, 2022, from https://www.entirety.biz/taiwan-ncc-announce-amendment-for-3g-mobile-telecommunication-terminal-equipment/

9M87. (2018, February 11). *EEW Earthquake Quick Report: Receive a notification 30 seconds before an earthquake, seize the golden time to escape, the savior of not receiving government alerts* (iOS, Android). Retrieved August 8, 2022, from https://ez3c.tw/6275

Prasanna, R., & Huggins, T. J. (2016). Factors affecting the acceptance of information systems supporting emergency operations centres. *Computers in Human Behavior*, *57*, 168-181.

Sarshar, P., Nunavath, V., & Radianti, J. (2015). On the usability of smartphone apps in emergencies: An HCI analysis of GDACSmobile and SmartRescue apps. In *Human-Computer Interaction: Interaction Technologies: 17th International Conference, HCI International 2015, Los Angeles, CA, USA, August 2-7, 2015, Proceedings, Part II 17* (pp. 765-774). Springer International Publishing.

Schmitt, B. (1999). Experiential marketing. *Journal of marketing management*, *15*(1-3), 53-67.

Stratmann, T. C., & Boll, S. (2016). Demon hunt-the role of endsley's demons of situation awareness in maritime accidents. In *Human-Centered and Error-Resilient Systems Development: IFIP WG 13.2/13.5 Joint Working Conference, 6th International Conference on Human-Centered Software Engineering, HCSE 2016, and 8th International Conference on Human Error, Safety, and System Development, HESSD 2016, Stockholm, Sweden, August 29-31, 2016, Proceedings 8* (pp. 203-212). Springer International Publishing.

Taiwan Inc. (2016). *Public Warning System Introduction.* Retrieved August 8, 2022, from http://www.emfsite.org.tw/PWS/p1-2.html

Tan, M. L., Prasanna, R., Stock, K., Doyle, E. E., Leonard, G., & Johnston, D. (2020). Modified usability framework for disaster apps: a qualitative thematic analysis of user reviews. *International Journal of Disaster Risk Science*, *11*, 615-629.

University of California. (n.d.) (2019, October,17). MyShake (Version 3.1.6) [Mobile phone software]. Berkeley, CA. Retrieved 2022, from https://apps.apple.com/us/app/myshake/id1467058529

Yahoo! Japan. (2018, March 26). *Yahoo! Disaster Prevention Bulletin App is renewed, and various disaster information and ‘actions to be taken now in the event of a disaster are displayed in an easy-to-understand manner*. Retrieved August 8, 2022, from https://about.yahoo.co.jp/pr/release/2018/03/26a/

Yang, L., Yang, S. H., & Plotnick, L. (2013). How the internet of things technology enhances emergency response operations. *Technological Forecasting and Social Change*, *80*(9), 1854-1867.

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