Smartphone Usability for Emergency Evacuation Applications

David Amores
University of Melbourne, Melbourne 3010, Australia
damores@student.unimelb.edu.au

Maria Vasardani
RMIT University, Melbourne 3000, Australia
mvasardani@rmit.edu.au

Egemen Tanin
University of Melbourne, Melbourne 3010, Australia
etanin@unimelb.edu.au

Abstract

Mobile phone ubiquity has allowed the implementation of a number of emergency-related evacuation aids. Yet, these applications still face a number of challenges in human-mobile interaction, namely: (1) lack of widely accepted mobile usability guidelines, (2) people's limited cognitive capacity when using mobile phones under stress, and (3) difficulty recreating emergency scenarios as experiments for usability testing. This study is intended as an initial view into smartphone usability under emergency evacuations by compiling a list of experimental observations and setting the ground for future research in cognitively-informed spatial algorithms and app design.

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Category Short Paper

1 Introduction

Wide adoption of smartphones has motivated creating technological aids for emergencies. There is extensive research in disaster management, specifically for indoor emergency evacuations. Still, emergency apps have yet to take off and enjoy broad user acceptance. This setback has been attributed to the lack of robust and widely deployed technologies such as indoor positioning or building mapping [16]. Although these factors are indeed limiting, we show in this paper that there is room for improvement in areas related to usability, as follows:

- **Use of design guidelines.** Previously proposed emergency applications often do not abide by best practices in mobile application design or navigation services design.
- **Consideration of cognition demands.** Related literature seldom performs usability testing and does not assess an application's cognitive demands, even though novel technologies, such as Augmented Reality (AR), have proven to be distracting [4].
- **Experiment validity (ecological validity).** A variety of experiments are done in literature but rarely do they recreate lifelike emergencies. Given that people may act differently during emergencies [17], experiments should resemble actual scenarios.

Thus, we propose that *beyond indoor technological setup issues, smartphone app usability is a key factor in evacuation app adoption.* This research in-progress constitutes an initial step towards building cognitively-ergonomic applications and spatial algorithms, thus, enabling the creation of advanced evacuation systems. As such, this paper intends to analyse the

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aforementioned issues by first collecting previous works that propose emergency applications (Section 2) and highlighting their impediments and impact in the lack of subsequent app adoption. In parallel, an experiment (Section 3) is performed where we develop an emergency application and set up a scenario resembling common characteristics of previous studies to take a closer look at the issues. Finally, a set of observations that consolidates the findings is presented in Section 4 and constitutes the main contribution of this ongoing work.

2 Related work

2.1 Smartphone usability and emergencies

General guidelines for best practices of mobile interface development have been proposed before [14]. In relation to navigation, usability guidelines for digital maps in mobile phones are given in [11] and mental load for different digital map representations is assessed in [7]. Complementary to these studies, our research aims to obtain insights from empirical data strictly related to applications for emergency scenarios. The context in these cases – e.g. the emergency – may play a bigger role than other scenarios, ultimately suggesting that alternative design and interaction paradigms can be used where cognition is a central factor.

Harrison *et al* [8] propose a high-level usability framework tailored for smartphones where cognitive load is added as an attribute besides more established ones such as effectiveness or efficiency. *Cognitive load* – the amount of mental effort needed to perform a task – is pertinent to mobile phones as users commonly engage in other activities in parallel such as driving or evacuating [8]. We argue that cognitive load is not only an additional usability attribute but a central one in emergency scenarios. Consequently, we give experimental observations evidencing the importance of cognitive load in usability testing. We believe evaluating cognitive load is especially relevant during emergencies where the main task is evacuating, and using a mobile phone should be a secondary and supporting task.

When proposing an application for emergencies, a variety of experiments can be done such as computer simulations, controlled lab experiments or drills. Choosing one of these experiments entails a trade-off between experimental control and *ecological validity* – i.e. the degree of correspondence between experimental and real-life settings [10]. People's behaviours in simulated emergencies differ to real-life emergencies [17], where people tend to exhibit non-adaptive behaviours [2]. A general framework for ecological validity in usability is given in [10]. However, there is a lack of more measurable and objective ways of quantifying ecological validity. Our research intends to advance this by providing observations on ecological validity in emergency experiments leading to more specific measures in future research.

2.2 Emergency applications

Table 1 lists representative studies that have previously proposed an application as an emergency evacuation aid. Column *DG* refers to whether the paper roughly mentions using mobile or map design guidelines for the app. Column *CL* indicates whether cognitive load is assessed within app testing. Column *EV* states the amount of ecological validity where ✗, ✓̸ and ✓are used to depict the amount of realism, and "–" when there is no user experiment.

It is unclear whether the listed works follow design guidelines or not, mainly because usability design is not the main focus of those studies. Based on app descriptions or screenshots, design guidelines are seen to be roughly followed but with a number of shortcomings. A system in [3] describes an app for delivering good routing instructions. However, temperature and distance are shown with text and no assessment is made as to whether users are able to

Table 1 Studies proposing the implementation of an emergency evacuation application.

Previous work	DG	CL	EV
Smartescape: A mobile smart individual fire evacuation system ... (2018) [3]	✓	X	X
Publish-subscribe smartphone sensing platform for the acute ... (2014) [13]	✓	✓	–
An indoor augmented-reality evacuation system for the ... (2012) [1]	X	X	–
Presenting evacuation instructions on mobile devices by means ... (2008) [5]	✓	X	✓✗
Handheld augmented reality indoor navigation with activity ... (2011) [12]	✓	X	–
An integrated building fire evacuation system with rfid and ... (2011) [6]	X	X	–
Integrating geographical information and augmented reality ... (2012) [15]	✓	X	✓✗
Indoor emergency evacuation service on autonomous navigation ... (2008) [9]	✓	X	–

grasp this info while moving. The problem with long texts is present in other applications as well [9, 1]. Good practices offered by underlying maps such as Google Maps are present in some works (e.g. [13]) but not in others where maps are built from scratch [15, 12].

Applications proposed in [1, 15, 12] convey route instructions with AR using the phone's camera, prompting users to hold their phones upright while walking. However, no assessment is done to check if users found this distracting. Indeed, AR has been proven to be diverting and hazardous for mobile users [4]. Other applications propose 3D [3, 5] or 2D maps [9] but cognitive load testing is lacking. Only one work [13] mentions doing it as a future direction. In fact, usability testing is rarely performed in these works. Because they are built for emergencies, we believe these studies must assess how distracting novel features may be.

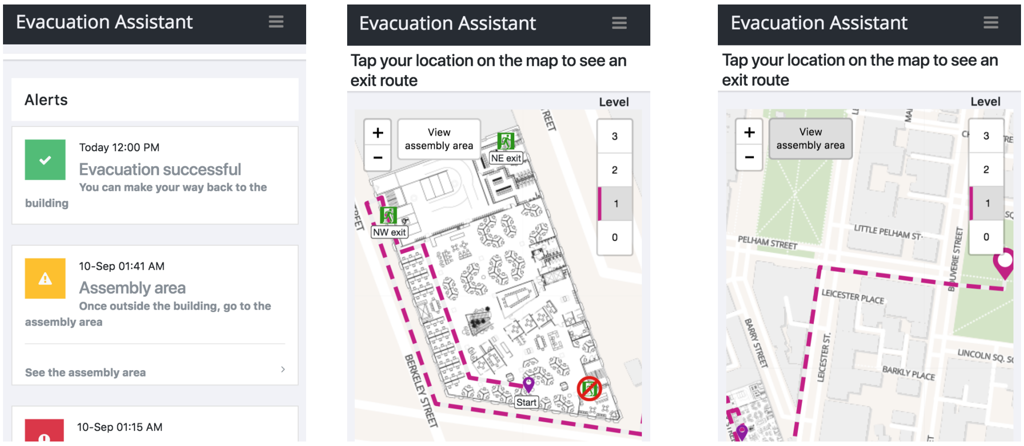
A subset of earlier studies in emergency management proposes applications but do not experiment with them [6, 9] and others use computer simulations [1]. Some studies perform experiments in controlled settings, providing participants specific tasks [3, 5, 15]. Low ecological validity could lead to unauthentic behaviours, jeopardising usability studies.

3 Experiment setup

The purpose of this preliminary experiment is to take a closer look at the aforementioned issues with smartphone usability during emergencies: design guidelines, cognitive load and ecological validity. The experiment consisted in equipping building occupants with a mobile application that would deliver evacuation information. The application was built to resemble a conventional smartphone app for emergency instruction conveyance, with two main features (Figure 1): **Messaging** – Push notifications, notifications history page – and **Map** – Multi-storey building map, personalised and dynamic exit routes, indoor landmarks, outdoor route to assembly area. A scheduled drill in a university staff building was chosen as the scenario. Seventy four (74) participants registered in our application prior to the drill.

To understand people's perception of the *application's design*, we gave participants a post-drill survey to fill. To assess the role *cognitive load* played, each participant was given access either to map-related features only, to notifications only, or to every feature, and compared phone interactions. We also compared the number and type of interactions (e.g. zooming, tapping) made with the app at different times of the evacuation. During the drill, participants had the liberty to use or disregard the application. To promote the use of the app, an exit was purposefully blocked and messages were sent throughout the drill. *Ecological validity* was assessed by observers during the drill. We collected three types of data:

- **Survey.** Answers to a survey including a general feedback question.
- **Interactions.** Recorded interactions with the app: taps, map zooming/panning.
- **Observations.** Experimental observations by the researchers during the drills.



(a) List of notifications. **(b)** Indoor exit route. **(c)** Outdoor route to assembly area.

Figure 1 Screenshots of the web mobile application used for the experiment.

4 Result analysis and discussion

The following subsections provide observations from the experiment in regards to the challenges mentioned in the introduction. These observations serve as a starting point to provide more specific and measurable guidelines and propositions for future research. Additionally, given that the main findings relate to cognitive load, we expect that these observations pave the way for visualisation and algorithms centered on human cognition.

4.1 Digital maps and mobile design

Observation 1: Users deem established apps as baselines. Feedback from the experiment showed that users regard popular applications as reference for newer apps, posing a challenge when building novel technologies (e.g. 3D models, AR). One participant expected to see his position on the map while another wished to have directions at each decision point and to be notified if a wrong way was taken. Both mentioned Google Maps as a reference point suggesting that established applications have placed expectations on users for future technologies. Users are also aware of general mobile design practices. A prevalent comment from participants who did not receive push notifications was the need to have them for quick and easy access to the application contents. This observation encourages developers to view established apps as a baseline when proposing new applications and developing new visualisation, communication, or design paradigms. During evacuation scenarios, adaptation of new methods would rather be difficult, at best.

4.2 Cognitive load and usability

Observation 2: Cognitive load is important and noticed by users. Participants realised the need to minimise the cognitive load the application takes from their working memory. Some participants show concern in their feedback regarding cognitive load: "you need to (...) mov(e) out of the building and PAYING ATTENTION to your surrounds, not stuck with your head in your device". Similar feedback was present in 6 out of 16 texts. Figure 2 reveals interaction patterns during the evacuation where local peaks are visible. The highest peak happens after the first alarm goes off, hinting that people were able to interact with the device before starting to move. The other peaks coincide with people getting out of the building and in the assembly area. That is, people were able to interact more with the device when they stopped moving. Thus, cognitively-intensive tasks should ideally happen at the start and end of evacuations and in between movement periods, and should be minimised otherwise. This contradicts AR, 3D or similar technologies that are being proposed.

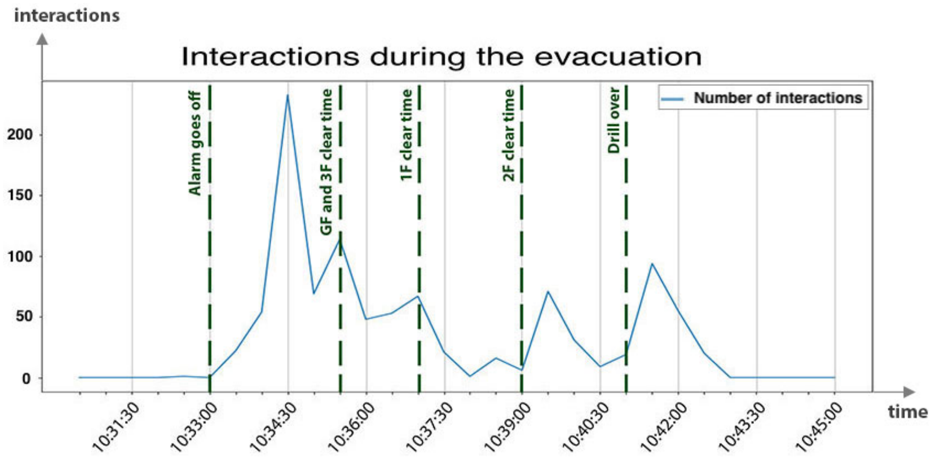
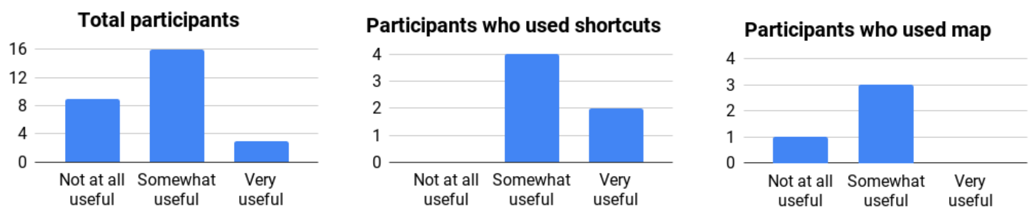


Figure 2 Number of interactions during the complete evacuation period.

Furthermore, Figure 3 shows the responses to a survey question regarding the app's usefulness. The first chart (Figure 3a) shows responses from every participant, revealing "somewhat useful" as the most common answer. Figure 3b shows the responses from people that made use of "shortcut" functions in the app such as push notifications or the assembly area button. These shortcuts allowed users rapid access to functionality, thus, requiring less cognitive load. None of these participants thought the app was not useful at all and, in fact, the proportion of "very useful" responses increases. On the other hand, Figure 3c shows the responses from people who made the most map interactions such as panning or zooming, using much of their cognitive load. The figure shows that no participant thought the app was very useful and the "not at all useful" response reappears. These results suggest that cognitive load due to app interactions impact the overall application's perceived usability.



(a) Total participants. **(b)** Used shortcut functions. **(c)** Interacted with map.

Figure 3 Segmented survey responses to question regarding usefulness.

4.3 Experiments' ecological validity

Observation 3: Ecological validity influences user behaviours. Column "EV" in Table 1 shows no checkmark (✓) value, highlighting that no experiment is realistic. Consequences of not having a realistic setting were exhibited in our experiment. People did not show signs of stress and used the mobile phone casually as if no emergency was ongoing, some explicitly confirmed they knew it was a drill. Others were seen coming back for sweaters, phones and even cigarettes. We suggest, then, adding urgency by replicating lifelike emergency attributes or using alternative methods such as giving a reward to the first few people who exit the building. Additionally, the lack of hazard cues was also a contributing factor. A group was observed figuring out if the emergency was real but as they did not see smoke, or other hint, they concluded it was a drill and exited casually. Adding fake smoke or loud noises can be ways to elicit more realistic behaviours, provided ethics approval. Moreover, some participants were more aware about the proximity of a drill. People who registered a week before the drill interacted with the app 25% less (in average) than people who registered the previous day. That is, late registrants were more aware about the coming drill so were more willing to participate, thus affecting genuine app usage behaviours.

5 Conclusion and future work

Our experiment allowed us to get first-hand experience and insights from smartphone use in emergency evacuations. This evidence suggests that usability considerations such as digital map design, cognitive load assessment and ecological validity do play a role in emergency evacuation app adoption, and designers should keep them in mind. Our literature review revealed common problems in the development of mobile applications for emergency evacuations. Data from the experiment ascertained these problems with emergency apps: (1) mobile map design is not properly implemented, (2) cognitive load is not accounted for, especially given the app's nature, and (3) ecological validity is not considered for testing. The resulting observations lay groundwork for the future: building smarter and personalised emergency evacuation systems. Future research aiming to achieve this goal will be oriented towards emergency aid design, cognitively-appropriate algorithms, and experiment design.

References

1 Junho Ahn and Richard Han. An indoor augmented-reality evacuation system for the Smartphone using personalized Pedometry. *Human-Centric Computing and Information Sciences*, 2(1):18, 2012.

2 David Amores, Maria Vasardani, and Egemen Tanin. Early Detection of Herding Behaviour during Emergency Evacuations. In *10th International Conference on Geographic Information Science (GIScience 2018)*. Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2018.

3 Umit Atila, Yasin Ortakci, Kasim Ozacar, Emrullah Demiral, and Ismail Karas. SmartEscape: A Mobile Smart Individual Fire Evacuation System Based on 3D Spatial Model. *ISPRS International Journal of Geo-Information*, 7(6):223, 2018.

4 John W Ayers, Eric C Leas, Mark Dredze, Jon-Patrick Allem, Jurek G Grabowski, and Linda Hill. Pokémon GO—a new distraction for drivers and pedestrians. *JAMA internal medicine*, 176(12):1865–1866, 2016.

5 Luca Chittaro and Daniele Nadalutti. Presenting evacuation instructions on mobile devices by means of location-aware 3D virtual environments. In *Proceedings of the 10th international conference on Human computer interaction with mobile devices and services*, pages 395–398. ACM, 2008.

6 Liou Chu and Shih-Jung Wu. An integrated building fire evacuation system with RFID and cloud computing. In *Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2011 Seventh International Conference on*, pages 17–20. IEEE, 2011.

7 Arzu Çöltekin, Benedikt Heil, Simone Garlandini, and Sara Irina Fabrikant. Evaluating the effectiveness of interactive map interface designs: a case study integrating usability metrics with eye-movement analysis. *Cartography and Geographic Information Science*, 36(1):5–17, 2009.

8 Rachel Harrison, Derek Flood, and David Duce. Usability of mobile applications: literature review and rationale for a new usability model. *Journal of Interaction Science*, 1(1):1, 2013.

9 Yutaka Inoue, Akio Sashima, Takeshi Ikeda, and Koichi Kurumatani. Indoor emergency evacuation service on autonomous navigation system using mobile phone. In *Universal Communication, 2008. ISUC'08. Second International Symposium on*, pages 79–85. IEEE, 2008.

10 Suzanne Kieffer, Ugo Braga Sangiorgi, and Jean Vanderdonckt. ECOVAL: A Framework for Increasing the Ecological Validity in Usability Testing. In *System Sciences (HICSS), 2015 48th Hawaii International Conference on*, pages 452–461. IEEE, 2015.

11 Liisa Kuparinen, Johanna Silvennoinen, and Hannakaisa Isomäki. Introducing usability heuristics for mobile map applications. In *Proceedings of the 26th International Cartographic Conference, August 25 30, 2013, Dresden, Germany, ISBN 978-1-907075-06-3*. International Cartographic Association, 2013.

12 Alessandro Mulloni, Hartmut Seichter, and Dieter Schmalstieg. Handheld augmented reality indoor navigation with activity-based instructions. In *Proceedings of the 13th international conference on human computer interaction with mobile devices and services*, pages 211–220. ACM, 2011.

13 Jaziar Radianti, Jose J Gonzalez, and Ole-Christoffer Granmo. Publish-subscribe smartphone sensing platform for the acute phase of a disaster: A framework for emergency management support. In *Pervasive Computing and Communications Workshops (PERCOM Workshops), 2014 IEEE International Conference on*, pages 285–290. IEEE, 2014.

14 Maria Shitkova, Justus Holler, Tobias Heide, Nico Clever, and Jörg Becker. Towards Usability Guidelines for Mobile Websites and Applications. In *Wirtschaftsinformatik*, pages 1603–1617, 2015.

15 Ming-Kuan Tsai, Yung-Ching Lee, Chung-Hsin Lu, Mei-Hsin Chen, Tien-Yin Chou, and Nie-Jia Yau. Integrating geographical information and augmented reality techniques for mobile escape guidelines on nuclear accident sites. *Journal of environmental radioactivity*, 109:36–44, 2012.

16 Lauri Wirola, Tommi A Laine, and Jari Syrjärinne. Mass-market requirements for indoor positioning and indoor navigation. In *Indoor Positioning and Indoor Navigation (IPIN), 2010 International Conference on*, pages 1–7. IEEE, 2010.

17 Xiaolin Yang, Zhongliang Wu, and Yingchun Li. Difference between real-life escape panic and mimic exercises in simulated situation with implications to the statistical physics models of emergency evacuation: The 2008 Wenchuan earthquake. *Physica A: Statistical Mechanics and its Applications*, 390(12):2375–2380, 2011.