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Emergency = Emergency? Usability evaluation of a novel emergency alerting system for cabin emergencies

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Abstract

Emergencies in aviation often create huge media attention because the number of people involved are high and flying was once considered to be risky, which is still in the mind of some passengers. This study evaluated how passengers and cabin crew classified cases of emergencies. Further, detailed design requirements on the emergency alerting interface were explored. Therefore, two different prototypes of an emergency alerting interface were presented to participants ($n = 160$) with the task to evaluate the perceived usability (SUS) and the subjective workload using NASA TLX. The SUS scores for both prototypes were above average indicating a good usability. Red was the preferred colour and a triangle shaped icon with SOS. Broad menu designs with more icons than text were the preference of the users. Passengers as well as cabin crew identified medical emergencies and unruly passengers as emergencies. However, passengers also mentioned technical failure as a possible case whereas cabin crew was more concerned about fire and smoke. This study has substantiated the need for an emergency alerting system since it is expected that the number of medical emergencies and unruly passengers will most likely increase in the future.

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1. Introduction

In aviation any kind of emergency has a potential to generate a major financial and personal damage. Although aviation is generally safe compared to other mass transportation, emergencies involving aircraft usually create a huge media attention. According to the commission regulation (EC) No. 859/2008 every operator needs to make sure that

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there are appropriate procedures in place which cover normal, abnormal and emergencies. According to skybrary.aero the definition of an abnormal situation is as follows: it is not possible to operate the aircraft in normal procedures, however the safety of the aircraft, passengers onboard, or on ground is not in danger. Whereas, emergencies are described as situations where the safety of the aircraft, onboard passengers or on the ground are endangered. In the Cabin Crew Operating Manual (CCOM) procedures for smoke/fire, emergency evacuation, depressurization, turbulences, flight crew incapacitation and bomb on board are described. However, how can cabin crew detect the different kinds of abnormal situation or emergencies and be prepared appropriately? For instance, in case of medical or technical issues passengers actively inform the cabin crew (Manikath and Li, 2022, p.2; Air Accident Investigation Report BA762, 2015, p.4). Since there is no emergency alerting system yet on an aircraft, the only way to inform cabin crew is either to press the Passenger Call Button (PCB) or yell for help (Manikath and Li, 2022, p.3). This study evaluates the usability and perceived workload of passengers using a refined emergency alerting prototype where the type of emergency can be chosen from a pre-defined menu.

RQ1: What are the differences in the perception of inflight cabin emergencies of passengers and cabin crew?

RQ2: How would passengers rate the usability of a simplified emergency alerting system compared with a detailed system?

RQ3: How would passengers perceive workload using a simplified emergency alerting system compared with a detailed system?

2. Methods

Emergency alerting systems can be found in daily life; however, the design varies depending on the functionality (Manikath et al., 2023, p.3). The objective of this study is to gain an in-depth understanding of the design of an emergency alerting system to report inflight cabin emergencies. A special focus was given to icon design, colour and menu navigation on the virtual emergency button designed for an IFE screen. Further, cabin crew being the secondary operator of the system were also asked for their preference on the design.

160 participants were invited for this research, with an age range from 18 to 62 years ($M = 38.2, SD = 10.8$). Most of the participants were male ($n = 119, 74.4\%$) and European ($n = 140, 87.5\%$). Purposive and snowball sampling were used to recruit the participants. Data was collected between December 2023 and July 2024. The institutional ethics approval was obtained by Cranfield University Research Ethics System (CURES/21010/2023). Each participant needed to read and sign the consent form before starting the questionnaire. Participants were able to end the survey at any time.

An online qualitative survey study was conducted to understand the requirements on a virtual emergency button. The first section of the questionnaire contained questions about basic demographics and travel experience to categorize the participants. Secondly, six different icons symbolizing “Emergency” were presented to the participants to understand their preference. Icon A, B, C and D are commonly used and standardized emergency icons according to ISO 7010, whereas Icon F depicted the target state, an “emergency vehicle” and Icon E shows a triangle with reference to the international signal of distress “SOS – Save our Souls” (see Fig.1).

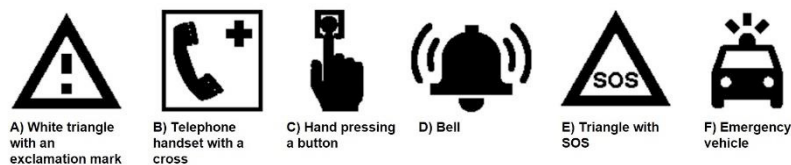


Fig. 1. Different proposals for Emergency sign

Lastly, two different prototypes of a virtual emergency button were shown to the passengers with the task of reporting a medical emergency to the cabin crew. The first prototype is the one initially described in Manikath and Li (2022), p.3. It is a two-step reporting measure with a confirmation and a reporting screen (see Fig.2).



Fig. 2. Simplified Emergency reporting with 3 screens according to Manikath and Li (2022), p.3

The second prototype is a further development on the initial prototype where the user can choose between the different types of emergencies: medical, safety critical and cabin smoke/fire (see Fig. 3).



Fig. 3. Refined Emergency reporting with four screens

After choosing the appropriate emergency category the user needs to confirm (cf. C in Fig. 3) the input. On the home screen the user will receive the information that the emergency call has been activated. It can be deactivated if needed by pressing the information on the confirmation screen (cf. D in Fig.3). The main difference to the initial prototype is that the user can choose from different emergency categories.

According to EU OPS 1.210 operators shall have procedures in place for normal, abnormal and emergency conditions. Appendix 1 to OPS 1.1045 Chapter B.3 defines the emergency and abnormal scenarios such as fire and smoke, depressurization etc. The scenarios mentioned in EU OPS 1 and the cabin crew operating manual, as well as feedback from the SME's have been used to develop the refined emergency menu of the second prototype.

Two different assessment tools were used to assess passengers feedback on the virtual emergency button: the System Usability Scale (SUS) and the NASA Task Load Index (NASA TLX). As per ISO 9241-11 three different criteria define usability (Bevan, et al. 2015, p.147):

- Effectiveness (ability of the user to solve a task using a system)
- Efficiency (number of resources needed to accomplish the task)
- Satisfaction (subjectively perceived opinion on the used system)

The SUS was developed by the engineer John Brooke in 1986 to provide a simple scale to evaluate the global usability of a system (Brooke, 1996, p.1). It consists of a 10-item questionnaire in which participants rate their experience after using a system on a five-point Likert scale. The total score of SUS ranges between 0 and 100, whereas a score above 68 is considered above average (Lewis, 2018, p.580). The NASA TLX is considered the “gold standard” in measuring the subjectively perceived workload (NASA TLX, 2020). The scale was developed by Sandra Hart in the 1980s. The scale measures overall workload on six different subscales: mental demand (MD), physical demand (PD), temporal demand (TD), performance (P), effort (E), frustration (F). The scale rates the workload on a scale of 20 points ranging from low (0) to high (20). In this study the raw TLX scores were used.

2.1. Research design

This research presented two different types of emergency alerting systems to participants to assess the usability and perceived workload operating these. The study was conducted online. All participants were given a consent form that included all the information about the research design. Participants needed to read and sign the consent form prior to participation. All participants completed the following procedures.:

1. complete the basic demographical information including age, gender, education, profession and air travel experience (5 minutes);
2. familiarization with the prototype (5 minutes);
3. report a pre-defined emergency using the prototype (5 minutes).

Afterwards, participants were completed two assessments: the usability (SUS) and subjective perceived workload (NASA TLX) (10 minutes). It took around 20 minutes for each participant to complete the online survey.

2.2. Prediction of the total task performance and execution time estimate for the simplified and refined prototype

In an emergency, every second counts. Therefore, it is useful to assess potential execution times of the two different prototypes to evaluate the needed time to accomplish the emergency call. The Keystroke-Level-Model (KLM-GOMS) was used to estimate and compare the time an expert operator might need to fulfil the task in the system (Card, Moran, Newell, 1980, p.396). The model uses four different “physical-motor operators” to describe the task execution: “K (keystroking), P (pointing), H (homing), D (drawing)”. Additionally, “M (mental)” is the user and R is the response by the system (Card et al., 1980, p.398). The execution time T_{ex} is calculated as the sum of all the operators: $T_{ex} = T_K + T_P + T_H + T_D + T_M + T_R$. The processing times were taken according to Card et al. (1980), p.399. The task completion times for both prototypes were calculated assuming an error-free expert performance. The response time of the system T_R was neglected ($T_R = 0$ ms) due to instant response times and for simplicity reasons. Default times were used for the mental Operator time ($T_M = 1350$ ms). It was decided to take the “average non-secretary typist” time for the keystroke or button press ($T_K = 280$ ms).

Four physical motor operators (navigate to (P), click on Emergency Button (K), navigate to (P) and click on Confirm / Reject Button (K)) and two mental operators (identify symbol for Emergency Button, identify symbol for Confirm / Reject Button, read and acknowledge confirmation message) were used for the simplified prototype. The keystroking time T_K was estimated according to Card et al. (1980) speed of an “average non-secretary typist” ($T_K = 280$ ms). The predicted task completion time for the simplified prototype was calculated with $T_{ex} = 3M + 2P + 2K = 6810$ ms. The refined prototype used four mental operators (identify symbol for Emergency Button, identify Emergency type, identify symbol for Confirm and Reject Button, read and acknowledge confirmation message) and 6 physical motor operators (Navigate to (P), click on Emergency Button (K); navigate to (P), click on Emergency type (K), navigate to (P), click on Confirm / Reject Button (K)). The predicted task completion time is around 30% higher than the simplified prototype and takes around $T_{ex} = 4M + 3P + 3K = 9540$ ms to complete. This analysis predicts that the simplified prototype would take less time (around 2.73 seconds less) to send an emergency message to the cabin crew.

3. Results

3.1. Usability and perceived workload evaluation of the refined prototype

96 participants rated the usability of the refined prototype for emergency alerting. The average SUS score was 73.9 ($SD = 19.3$). A one-way ANOVA was conducted to assess the effects of user age on the usability ratings (as measured by the SUS). Participants were divided into four age groups. Age group 1: 19-29 years ($M = 78.2$, $SD = 14.4$). Age group 2: 30-39 years ($M = 72.9$, $SD = 21.3$). Age group 3: 40- 49 years ($M = 72.0$, $SD = 21.0$). Age group 4. 50 + years ($M = 72.5$, $SD = 20.5$). Data was normally distributed for each group tested according to the Shapiro- Wilk Test ($p > .05$). Further there was homogeneity of variance (Levene’s test $p > .05$). No statistical difference could be found in the SUS scores for the different age groups, $F(92, 3) = 0.52$, $p = .666$.

96 participants evaluated their subjectively perceived workload using NASA TLX. The average TLX score was 24.1 ($SD = 22.8$). Since the data was not normally distributed, a Kruskal-Wallis-Test was conducted. The results indicate no significant difference on the raw NASA TLX score and the different age groups, $H(3) = 2.11, p = .550$. Furthermore, the results of the one-way MANOVA revealed, that there is no statistically significant difference between the age groups on the combined dependent variables (TLX sub scores: MD, PD, TD, P, E, F), $F(18, 246.56) = 1.50, p = .091, \text{partial } \eta^2 = 0.09, \text{Wilks} - \Lambda = 0.75$.

3.2. Differences between the two prototypes – usability and perceived workload

117 participants (96 participants on the new prototype and 21 participants on the old prototype) assessed the usability of the two prototypes independently. Since the data was not normally distributed a Mann-Whitney-U-Test was calculated to determine the differences in the System Usability Scores for the two prototypes. The distributions did not differ between both groups, Kolmogorov-Smirnov $p < 0.05$. There was no statistically significant difference in the median System Usability Scores for the new prototype ($Mdn = 77.5$) and the old prototype ($Mdn = 80.3$), $U = 882.50, Z = -0.89, p = .375$.

131 participants (109 participants on the new prototype and 22 participants on the old prototype) rated their perceived workload on the NASA TLX scale after using the prototypes independently. An independent sample t-test revealed that there was no statistically significant difference regarding the raw TLX scores between the two prototypes, $t(129) = 0.01, p = .71$.

3.3. Design of the Emergency Button

In total 160 passengers ($M = 38.2, SD = 10.8$) answered this section. 119 male participant, 38 female and 3 preferred not to reveal their gender. Participants were shown six different icons and four different colours on the proposed Emergency Button. It was necessary to choose one preference on the icon and the colour. In total 89 (56%) persons preferred the icon depicting a “triangle with SOS” inside. The second most preferred icon was the “telephone handset with a cross” ($n = 41, 26\%$). The least selected one was the “emergency vehicle” ($n = 2, 1\%$). A Chi-Square analysis has been conducted to assess the differences between gender and the preference on the icon. The Monte-Carlo simulation revealed that there is no significant difference between gender and the preference on the icon ($\chi^2(8) = 11.65, p = .168, \phi = 0.27$). Additionally, there was also no significant difference between age groups and the preference on the icon ($\chi^2(12) = 9.85, p = .659, \phi = 0.25$).

Further, the majority chose the colour “red” (R:1, G:0, B:0) ($n = 88, 55\%$) and “yellow” (R:1, G:0.8, B:0) ($n = 45, 28\%$). The least preferred colour participants associated with an emergency was green (R:0.57, G:0.82, B:0.31) ($n = 2, 1\%$). Results from the Monte-Carlo simulation show that there was a significant difference between gender and the preferred colour ($\chi^2(6) = 26.39, p < .001, \phi = 0.41$). Moreover, there was no significant difference between age groups and the preferred colour ($\chi^2(9) = 11.86, p = .222, \phi = 0.272$).

3.4. Results of the qualitative analysis

After completing the usability and workload assessment of the two prototypes, passengers ($n = 21$) and cabin crew ($n = 11$) were asked open ended questions about what they define as an emergency and which information is needed to report or process an emergency successfully (multiple answers were allowed). From a passenger’s perspective the three most mentioned cases for emergencies were medical emergencies ($n = 13, 36\%$), aircraft damage (interior or exterior) / technical failure ($n = 7, 19\%$) and unruly passengers ($n = 5, 14\%$). In contrast, the majority of cabin crew pointed out fire and smoke ($n = 11, 22\%$), secondly unruly passengers ($n = 10, 20\%$) and lastly medical emergencies ($n = 9, 18\%$). Additionally, passengers were asked which additional information they need to successfully report an emergency and which information cabin crew needs to process an emergency. Most of the passengers stated that no further information ($n = 10, 48\%$) as already included in the prototypes would be needed, secondly the type of ($n = 4, 19\%$) and lastly the location of the emergency ($n = 3, 14\%$) would be needed to report an emergency. Whereas

cabin crew mentioned the “five Ws”: what happened ($n = 8, 25\%$), who is involved ($n = 7, 22\%$), where ($n = 6, 19\%$), when ($n = 4, 13\%$) how ($n = 3, 9\%$) as essentially needed information.

3.5. Summary

To summarize the results the statistics clearly show that a medical emergency and an unruly passenger is considered an emergency for the crew and the passenger. However, the crew perception for an emergency in case of a technical failure is less critical than the perception of the passengers. For most participants of the questionnaire, the colour red and the SOS symbol, and a warning triangle sign were correlated best with an emergency. The SUS scores of both prototypes were above average and indicate a good usability of the design.

4. Discussion

This study evaluated two different designs of a virtual emergency alerting screen design to assess passengers' preferences. The findings of this study are beneficial for the design of a future emergency alerting system and provide valuable information on the requirements of passengers, but also cabin crew. Firstly, this study found out what passengers and cabin crew define as an inflight emergency. Both target groups identified medical emergencies and unruly passengers as cases for inflight emergencies. This finding is in line with Gendreau and DeJohn (2002), p.1067. It is highly likely that the number of medical events will increase as the population ages and the number of passengers is increasing. Although most of the medical events are not serious, approximately 13% of all inflight medical incidents onboard domestic aircraft in the 2000 report of the FAA resulted in flight diversions (Gendreau and DeJohn, 2002, p.1067). Further, according to IATA, there was an increase in reported unruly passenger incidents in 2023, with 1 incident occurring for every 480 flights, compared to 2022, when there was 1 incident for every 568 flights. (IATA, 2024, p.1). Most frequently passengers failed to comply with instructions of the crew. Additionally, passengers identified technical failure of the aircraft as one possible reason for an emergency. An explanation why passengers classified damages to the aircraft as an emergency could be due to flight anxiety. According to Bor (2007), p.210 an underlying “fear of crashing” and the perceived loss of control are reasons why people could develop flight anxiety. A remedy for these passengers could already be to explain the basic aerodynamic principles and the operational procedures of flight conduct (e.g. how air traffic controllers work, maintenance of aircraft etc.) (Bor, 2007, p.210). Cabin crew in contrast are well-trained in the basics of aviation aircraft technology and operational procedures, furthermore, used to air travel and therefore able to correctly perceive the risks of crashing. Flight attendants perceive fire and smoke more dangerously than technical failure because they are supposed to be the first responders and are engaged in active firefighting. In fact, according to commission regulation (EU) No 290/2012 Appendix 1 to Part-CC “General theoretical knowledge of aviation and aviation regulations [...]”, basic knowledge about aeromedical basic and first aid, and “Fire and Smoke Training” with an emphasis on the detection of source of the fire are mandatory training content to obtain a cabin crew attestation. Contrary to the active role of flight attendants during fire or smoke incidents, passengers have a passive role and need to fully rely on the technical equipment and the skills of cabin crew. The five Ws date back to the ancient Greek and are embedded in the seven questions (who, what, where, (with what), why, how, when) to tell stories clearly (Bešker, 2009, p.49). The five Ws are an essential part of information retrieval during emergency management and are vital to ensure the correct response.

4.1. Design recommendations for the inflight Emergency Button

Regarding the symbols the most preferred icon was the “triangle with SOS” and the colour red. Rounded shapes are usually more favored by users according to research (Nissen et al., 2024, p.3) because in nature round shaped food (e.g. apples or berries) are safe to touch and do not harm. Whereas sharp shapes (such as sharp stones or thorn) signal that they might cut and harm. For an emergency button a sharp shaped icon such as the triangle would be the optimal choice because the triangle is also used in warning signs according to ISO7010. In general, symbols are not independent from its cultural context and should therefore not being used if the application contradicts to its cultural meaning (Romberg, et al., 1998, p.140). A prominent example can be found in ISO7010 where the red crescent instead

of the cross is predominantly used in areas with most of Muslim population. Further, the sharp shape could prevent users to only use the button for real emergencies and not like the existing passenger call button for everything or to expedite a service request. Participants further mentioned that the triangle is a simple, yet clear to understand symbol which is generally used for warning signs. Regarding colour coding, previous research has shown that the use of colour depends on its context (Romberg, et al., 1998, p.140). According to ISO 7010 red is used for prohibition or as fire safety sign. This is also true across cultures where red is used in traffic signals or stop signs (Nissen, et al., 2024, p.3). From an evolutionary perspective this colour is related to fire or fresh blood and therefore commonly associated as a threat (King, 2005, p.239; Nissen et al., 2024, p.3). Additionally, the colour red for an emergency button is quite common in everyday's life and could indicate a warning/ threat not to use the button for non-emergencies. Most of the participants also stated that the colour red indicates "danger, warning" and "you wouldn't press a red button unless it's really urgent". In a previous study it was found that the colours red and green were understood worldwide regarding user interfaces for production machines (Romberg, et al., 1998, p.140). This study could not prove any cross-cultural differences in the colour and icon since the majority of participants was of European descent ($n=140$, 88%). One also mentioned the parallel to the indications in cars where yellow gives you an alert / information and red is used for faults. SOS is an international morse code to call for help in an emergency (Fathom, 2023). Participants of the study mentioned that SOS is a well-known code ("common knowledge") used to indicate an emergency. However, it was criticized that the font used in the icon was too small and should be bigger. To summarize the design of the emergency button needs to reflect that it should not be used for standard requests. It should be clear and simple in the design. Therefore, the colour red and amber seem to be good choices as well as the use of sharp shapes such as the triangle to avoid misuse.

4.2. Detailed design recommendations for the virtual emergency menu design

Two different prototypes for the virtual emergency button have been compared regarding their usability and perceived workload in this study. The simplified version consists only of three screens and a predicted task completion time of $T_{ex} = 6.81$ s. The SUS score for this prototype was $M = 79.5$, $SD = 3.0$. The goal of the refined prototype was to provide cabin crew with as much information as possible on the emergency type. Therefore, the screen design consisted of four different screens and an estimated task execution time $T_{ex} = 9.54$ s. Although the task completion time is longer for the refined prototype there was no statistically significant difference regarding usability or perceived workload. The SUS score of 73.9 indicate an above average usability. The interface design type in the refined prototype is a menu-driven interface, meaning that the user chooses from a predefined selection. According to Ro et al. (2008), p.730 menu-driven interfaces are easy to learn which can also be seen in the sub score for learnability for the refined prototype ($M = 17.6$, $SD = 0.4$) which is higher than for the simple prototype ($M = 17.1$, $SD = 0.9$). Therefore, the organization of the information on the display need to be carefully organized to improve information retrieval (Kiger, 1984, p.201). Studies suggest that the breadth of the menu shall be bigger than the sublevels of the menu tree, whereas the levels in the tree shall not exceed two or three (Kiger, 1984, p.201; Landauer, Nachbar, 1985, p.76). This is in line with the design of both prototypes where the depth of the tree is not exceeding 3 levels. Some of the participants also mentioned to make the design more "simple", complained about "too many clicks" and to include "more icons". The use of symbols from an information processing perspective is useful to predict or explain unfamiliar behavior of the environment and they belong to the "human world of meaning" (Rasmussen, 1983, p.260). According to participants feedback the refined prototype could be simplified by decreasing the depth of the menu tree and include more icons on the first level. Most importantly, clear instructions on when to use the emergency button are necessary ("Like a first little tutorial before the flight") to avoid accidental use and misuse to expedite pending service requests ("Make it clear what the difference is between service call and emergency call. I can already imagine that this is often erroneously pressed by passengers and that crew will become negligent once it is activated."). It could be argued that fining, as it is usually done for other emergency buttons e.g. in trains could be an effective measure to prevent misuse. Lastly, there are also limitations to this study such as no stress was induced before the participants evaluated the prototypes for their usability and perceived workload.

5. Conclusion

The perception of emergencies highly depends on personal values and personal experience. This becomes evident in the Emergency Room, where healthcare professionals need to rank the patients according to the criticality of their ailments to prioritize and allocate scarce resources. This study helped to understand the differences in emergency classification in air travel. Although passengers and cabin crew identified medical emergencies and unruly passengers as possible emergencies, passengers were also concerned about technical failure whereas cabin crew was more concerned about fire and smoke in the cabin. Since the cases of medical emergencies and unruly passengers are expected to increase in the near future, the need for an emergency alerting system seems to be inevitable. This study provided valuable insights into the detailed design of such an interface. Regarding the appearance of the emergency button itself the preference was on red or amber colour and the triangle shaped icon with SOS. For cabin crew it is important to have as much information on the situation as possible (5 Ws), however, passengers preferred a simpler design which could be realized by using more icons (broadening of the menu and reducing the sub levels). Cross-cultural differences and the effects of stress on the usability of the emergency button need to be assessed in future studies.

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