Application of Augmented Reality in Aviation: Improving Engagement of Cabin Crew during Emergency Procedures Training

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ABSTRACT

The main duty of the cabin crew is to ensure the safety of all passengers onboard and are crucial during emergency situations. It is mandatory for cabin crew to attend the annual Emergency Procedures Training (EPT) to be able to operate as cabin crew regardless of the seniority. Despite the high importance, this training can be long and bulky leading to boredom and lack of engagement, hence jeopardizing the importance of in-flight safety procedures. Although Augmented Reality (AR) can potentially address this issue while enhancing engagement and learning retention, limited work has been undertaken to apply this technology to EPT. As such, this paper investigates whether augmented reality can effectively improve user engagement during emergency procedures training in the context of aviation. In this endeavor, an AR-based application was developed and is presented in this paper. The Positive Engagement Evaluation Method (PEEM) was then used to assess engagement among the 45 cabin-crew of the national carrier. From the PEEM matrix, the positive engagement score obtained was 10.58 and mean scores from the questionnaire ranged from 3 to 4.7. This highlights that Augmented Reality has the potential to enhance the motivation and engagement of users during the emergency procedures training, although a few limitations were identified.

CCS CONCEPTS

Human-centered computing → Human computer interaction (HCI) →Interaction paradigms → Mixed/ augmented reality

KEYWORDS

Cabin Crew Training, Emergency Procedures Training, Augmented Reality, Aviation, Engagement, Mobile Application.

1 Introduction

Although the main duty of the cabin crew is often perceived to be customer service onboard, their main and primordial responsibility is ensuring safety of all passengers on a flight [1]. It is said that a well-trained crew is a crucial factor in emergency situations [2]. This statement can be applicable in rare cases like the crash of flight EK 521 in 2016 where the Emirates cabin crew have been able to evacuate all the 282 passengers onboard in less than 90 seconds without any injury [3]. In accordance with the regulations of the two aviation authorities, International Air Transport Association (IATA) and International Civil Aviation Organization (ICAO), cabin crew training consists of initial training for new recruits and a mandatory annual refresher Emergency Procedures Training (EPT) for existing cabin crew members [4].

Globally, EPT includes knowledge development on safety equipment and their locations on different aircraft types, smoke and fire drill onboard, sea evacuation procedures and first aid training [5]. In general, EPT involves 6 hours training and are within traditional classroom settings with instructors going through the content from the manual, followed by examinations. However, the long hour monologue may lead to boredom, tiredness, lack of attention and interest and engagement resulting in cabin crew members losing motivation to give the required attention hence jeopardizing the importance of in-flight safety procedures [6].

Engagement in the learning field can be defined as the behavioral intensity and emotional quality of one's involvement during a task [7]. It is said that engagement of learners during training is a determining factor in success [8]. As for motivation, it is said to be the basis of cognitive engagement, where in a psychological perspective, motivation is perceived as the driving force to push learners to be involved in the training [9]. It is said that the motivation is derived from the interest built up while performing a task leading to spontaneous satisfaction from it [10]. The lack of engagement among learners results in reduced focus and attention during training and hence the motivation to exert the required involvement is decreased. The root causes of the lack of engagement was found to be the traditional classroom settings, where the absence of interactive activities and long hours of

lectures do neither provide hands-on experience nor provide opportunities for participation [8].

In order to enhance motivation and engagement in the learning process, the use of technological or digital tools are preferred to traditional methods [11]. Results from studies also suggest that the interactive and immersive features of technologies like Augmented Reality (AR) are designed to grab more attention and enhance the learning experience hence increase the motivation among learners [12]. Augmented reality (AR) is a technology developed to merge the real world and the virtual world by overlaying the digital data on real world views. AR enhances the user's perception of and the interaction with the real world and can apply to all senses [13]. Even though AR was accepted and adopted in the aviation sector as an efficient tool for training [14], limited work has been undertaken to assess whether this technology can effectively enhance engagement during EPT.

In order to address this gap, this paper investigates whether augmented reality can effectively improve user engagement during emergency procedures training in the context of aviation. This paper is structured as follows: in the next section, existing work involving the use of AR in aviation is reviewed followed by describing such an innovative AR-based EPT training tool. In the fourth section, the evaluation method is described, before discussing the findings of the study and concluding the paper.

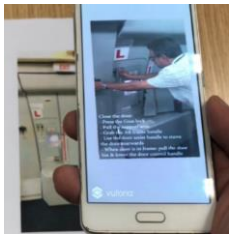
2 Related Works

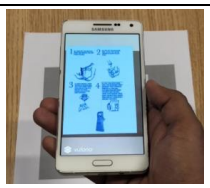
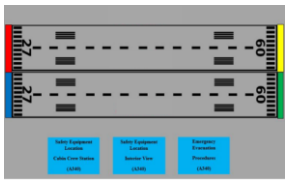
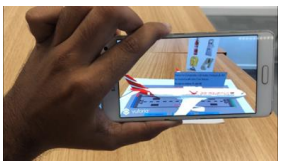
Over the years, there have been changes in the method of training cabin crew members whereby involving use of innovative technologies to enhance the learning experience. In terms of application of AR in this area, limited work has been undertaken. Among the related work, Virgin Atlantic has innovated its training process whereby introducing AR to train crew members [15]. Using the iOS-based application, the application enables cabin crew to walk through the cabin and acquire knowledge on the layout of the Boeing 787 Dreamliner of Virgin Atlantic without even visiting the aircraft or a simulator. The AR simulates a realistic full view of the cabin interior that complements the existing classroom training. The main drawback of this application is the fact that it has been designed especially for the Boeing 787 of Virgin Atlantic. This application is mostly for a cabin tour and commercial training and not EPT. Similarly, Air New Zealand cabin crew have been introduced to AR through the Microsoft Hologram Lenses, which is in the form of a headset where the main purpose is to display information on the passengers' moods onboard in order to improve the customer service. This application has a different focus and is neither meant for training purposes nor for EPT [16]. As such, none of the existing solutions are meant for training on EPT and none of them investigate influences on user engagement during such training complemented using AR.

3 The Prototype

Owing to the lack of existing solutions that could be utilized to achieve the purpose of this paper, a marker-based AR application called AvGeek AR was designed and implemented. The purpose of this tool is to train cabin crew members on aspects pertaining to passenger safety within an aircraft. AvGeek AR was developed using Unity and Vuforia due to the popularity of these tools in building AR applications [17]. Also, at the time of implementation, Unity and Vuforia were the only tools that support 3D models in the artefact produced. The app consists of multiple image targets with the aim of overlaying digital information to enhance the cabin crew learning experience. The image targets are related to some sections of the EPT such as safety equipment, safety equipment location and emergency procedures. In order to make the app more interactive, features such as virtual buttons, videos and voice over tutorial were used. The image targets and corresponding augmented overlays and features are displayed in **Error! Reference source not found.**.

Table 1: Image targets and augmented features of AvGeek AR

Image Target	Augmented Features
 **Description**: Airbus A340 door	 **Description**:Video tutorial of aircraft door operations
 **Description**: Fire Equipment	 **Description**: 3D model of the equipment along with a voice over tutorial of how to use it.
 **Description**: First Aid Kit	 **Description**: 3D model of the kit displaying what is inside the first aid box.

 **Description**: Protective Breathing Equipment Box	 **Description**: Demo on how to use this equipment.
 **Description**: Image target with virtual buttons representing sections of the EPT	 **Description**: The scene changes accordingly when the virtual buttons are triggered.

4 Evaluation

As stated previously, the main objective of this study is to demonstrate whether engagement of the cabin crew is enhanced during their safety training using augmented reality. Following creation of the prototype, evaluation was carried out in order to fulfill the purpose of his paper. In this section, the evaluation framework utilized is described.

4.1 Evaluation Method

For evaluating the engagement of cabin crew members when using AvGeek AR, the Positive Engagement Evaluation Model (PEEM) was utilized due to its relevance and popularity in assessing user engagement. effectiveness of interactive and immersive technologies specific to AR [18, 20]. The PEEM matrix is based on psychological components, psychological flow theory, narrative transportation theory, and several neurological concepts in order to evaluate the engagement, immersion and PEEM includes a decision-tree that help in determining which matrix to apply: one that focuses on task-based experiences or one that focuses on narrative-based experiences [19]. In the case of AvGeek AR, the task-based experience matrix was deemed appropriate because this approach combines complete, qualitative experience in interactive mobile augmented reality applications. The matrix is represented by 8 attributes which are described in **Error! Reference source not found.**. Positive engagement is then determined from the net sum of all the 8 scores. Based on the attributes, a PEEM questionnaire was prepared. The items in the questionnaire were quantitative ones and each criterion was assessed against a 5-point Likert scale where 1 meant 'completely disagree' and 5 was 'completely agree'. The PEEM questionnaire is as illustrated in **Error! Reference source not found.**.

4.2 Evaluation Procedures

After preparation of the data collection instrument, cabin crew members of the national carrier were invited to participate in the study. This included senior flight pursers, flight pursers and regular cabin crew. Among the 60 participants invited, only 45 agreed to participate due to time constraints. This also meets the minimum participant requirement for such study [19] Evaluation was performed during the annual EPT at the flight operations department of Air Mauritius. To initiate the process, small groups of 5 participants were briefed on the purpose of the study and the AR tool involved. Then, confidentiality of data collection was explained and informed consent for participation, data collection and photography were sought from the participants. Then, participants were given a small demonstration of how to use the app and manipulate the image targets as guideline. Following the demonstration, participants were handed out mobile phones containing the application and a copy of the image targets for use individually. Participants then had to individually utilize AvGeek AR, while exploring all the features present and going through the learning scenarios while making use of the image targets given in **Error! Reference source not found.**. The cabin crew were assisted in case of any technical issue or inability to perform a task and in parallel, the time taken per participant was noted. Users could interact with each other within the small teams, while also catering for collaboration, which is part of the PEEM. Finally, users were asked to fill the PEEM questionnaire. For this task, the cabin crew were left on their own so that they could give honest feedbacks without any influence. Upon completion of this process, the questionnaires were collected, and the cabin crew were thanked for their participation in the process. After the data collection sessions, the answers from the questionnaires were processed on Tableau for data analysis. Tableau was chosen for data analysis as the software provide comprehensible instructions, examples and visual analysis tools. During the analytical process, the average net scores was calculated for each PEEM attribute and these values were summed up to give the total score. The net experience is the value to measure engagement and is derived from the following formula [19]:

Net Experience = Total Score / 8

Table 2: Attributes of PEEM [18,19]

PEEM Attribute	Description	Measured Item
Goals	This element addresses whether the goals of the app are clearly aligned to user needs [19].	G1. I was able to learn about safety equipment, safety equipment locations and some important procedures with AR.
		G2. I understood how the mobile application works and how to manipulate the objects (mobile phone, virtual button and targets).
Attention	This attribute investigates how user-friendly, easy or interesting application tasks are. Attention is the primary stage to user engagement [19].	A1. I found the application user friendly and it was easy for me to perform the tasks (scan the image targets and use the virtual buttons to display different information).
		A2. The features (3D model of aircraft, safety equipment, Cabin interior, videos and voice over tutorials) of the application were appealing and grabbed my attention.
Content	The content section explores the media used in the application and whether the media used are smooth in execution, target the user's emotions, and are relevant to the goals [18].	Ct1. The 3D models, videos, images used and displayed were relevant in enhancing learning experience during EPT.
		Ct2. Reviewing safety equipment locations, safety equipment and safety procedures using the AR application evoked positive emotions (pleasure, curiosity or fascination).
		Ct3. The sections of EPT chosen (safety equipment, safety equipment location and safety procedures) are useful, important and relevant to Cabin Crew safety training.
Concentration	Users should receive feedback to assist with learning and guidance through the tasks [18].	Cn1. The use of sound, 3D models, images and video led to better retention of the content covered from Emergency Procedures Training.
		Cn2. I felt the learning process less monotonous and bulky while using the application.
Identity	The application must include tasks that incorporate the user into the experience to promote skill-building and mastery [19].	Id1. I felt absorbed and completely engaged while using the application during the training.
		Id2. The application somewhat helped me built my skills on manipulating safety equipment and performing safety procedures.
Interaction	This element investigates whether the application provides a clear progression of the different tasks without any interruptions such as errors and has content that adjusts to the user's needs [18].	In1. The virtual buttons and image targets made me feel in control over my actions.
		In2. I was not bothered by any interruptions such as error messages or irrelevant information.
		In3. The use of a mobile application with the image targets and virtual buttons concept made the training more interactive.
Collaboration	The application should include opportunities for collaborating with others and support social interaction and engagement [18].	Cb1. I collaborated more with others while using the app (helping each other while using the app or discussing about how it works).
Satisfaction	For satisfaction, users should feel motivated or encouraged to reuse the application and recommend it to the others [19].	S1. Overall, I enjoyed the experience and felt happy and satisfied after using the app for EPT.
		S2. I think the application could be a potential support to Cabin crew members during EPT.
		S3. I may consider using the application again for EPT and personal review.
		S4. I can recommend this app to my fellow cabin crew members.

5 Results and Discussion

Using the methodology described in the previous section, the key results from the user evaluation is compiled in Table 3, depicting the mean score distribution for each item of the PEEM. Among the 45 participants, 64.4% were recurrent cabin crew members, 20% were Senior Flight Pursers (SFP) and 15.6% were Flight Pursers (FP). Despite having different experience levels, all the cabin crew undergo the same training hence the evaluation was done indiscriminately. The application of the PEEM and the matrix to the results are then discussed next.

5.1 Goals

For this attribute the cabin crew were asked whether the goals of the AR-based application helped to enhance learning about safety equipment, safety locations and safety procedures. Results showed that 48.9% of the participants agreed and 37.8% strongly agreed about this statement (G1). According to the participants, the positive finding was particularly because the overlays within the application provided complimentary information that helped the learning process. On the other hand, 4.4% of the cabin crew partially learnt the section with AR, 8.9% were neutral for this question and these were because these participants felt that more information could be added to further enhance knowledge. Moreover, for the same PEEM attribute, it is important for the users to understand how to use the mobile application and in this case how to manipulate the different objects. For this aspect, the responses were only positive as 100% respectively understood the functionalities of the app.

5.2 Attention

As mentioned earlier, attention is the primary stage for user engagement [19] and hence, it is important that the features of the application are appealing in order to engage the users. Another aspect required to grasp users' attention is user friendliness of the app. Positive responses were obtained where 100% of the cabin crew felt the application was easy to use and the tasks were easily performed. This was due to the complementary information available within the application to guide the user in doing the tasks. Similarly, 97.8 % of participants found the features such as the 3D models, videos, images and virtual buttons appealing and agreed that these features grabbed their attention.

5.3 Content

Content plays a key role in evoking positive emotions such as interest, curiosity, enjoyment and pleasure which may lead to enhancing the users' motivation during the training. From the evaluation, 95.6% of the cabin crew felt that the app kept them interested and curious and somehow motivated them to explore the app more. However, 4.4% of participants were either neutral or disagreed about this statement (Ct1) because features to enable zooming of some overlays were missing. Moreover, 88.9% of participants perceived that positive emotions were evoked (pleasure and curiosity) after using Avgeek AR for EPT. This could be attributed to the fact that these users were utilizing an AR based application for the first time. As for the rest of participants who rated this statement below 4, more animated and 3D content could have been included to further enhance the pleasing experience. In addition, an average of 95.6 % found the content relevant to the training against 4.4% who found disagreed about Ct3 because more scenarios in relation to EPT could have been included according to this group of participants.

5.4 Concentration

As for this attribute, the cabin crew were asked whether using the AR application can lead into better retention of the training content. Hence for this attribute, the difference between regular classroom training and using AR tool was evaluated. 93.3% of the cabin crew perceived to better retain the content covered as compared to reading regular manuals. However, 4.4% believed that retention was only partially enhanced while using the application. This was because through Avgeek AR, only key EPT training information is provided whereas a manual is more comprehensive. From further analysis, it was found that only Senior Flight Pursers (SFP) responded negatively to retention factor most probably due to their experience in the profession. On average, 93.4% of the cabin crew found that using Avgeek AR made EPT less monotonous and bulky compared to the use of manuals.

5.5 Identity

Identity is the attribute where users can express how absorbed and engaged, they were while using the application. Results showed that 48.9% and 44.4% of participants respectively agreed and strongly agreed to have felt absorbed and engaged while using the application. This was particularly because of the AR overlays which enabled end users to interact and dynamically obtain information on EPT. In addition, the use of multimedia content including voice, animations and 3D models enabled an engaging experience according to this group of participants. Besides, 6.6% of participants felt otherwise for Id1 and this was because this group felt that the application provides the same information at each utilization. According to this small group, more dynamic contents could have been added to display constructively different contents at every use. On the other hand, slightly lower scores were obtained for Id2. Only 53.6% of participants agreed or strongly agreed that the AR tool helped to build skills on manipulating safety equipment and performing safety procedures.

Table 3: PEEM Questionnaire Scores

PEEM Attribute	Measured Item	Score				
		1	2	3	4	5
Goals	G1. I was able to learn about safety equipment, safety equipment locations and some important procedures with AR.	0%	4.4%	8.9%	48.9%	37.8%
	G2. I understood how the mobile application works and how to manipulate the objects (mobile phone, virtual button and targets).	0%	0%	0%	42.2%	57.8%
Attention	A1. I found the application user friendly and it was easy for me to perform the tasks (scan the image targets and use the virtual buttons to display different information).	0%	0%	0%	33.3%	66.7%
	A2. The features (3D model of aircraft, safety equipment, Cabin interior, videos and voice over tutorials) of the application were appealing and grabbed my attention.	0%	0%	2.2%	36.6%	62.2%
Content	Ct1. The 3D models, videos, images used and displayed were relevant in enhancing learning experience.	0%	2.2%	2.2%	40%	55.6%
	Ct2. Reviewing safety equipment locations, safety equipment and safety procedures using the AR application evoked positive emotions (pleasure, curiosity).	0%	3%	4.4%	42.2%	46.7%
	Ct3. The sections of EPT chosen (safety equipment, safety equipment location and safety procedures) are useful, important and relevant to Cabin Crew safety training.	0%	4.4%	0%	42.2%	53.3%
Concentration	Cn1. The use of sound, 3D models, images and video led to better retention of the content covered from Emergency Procedures Training.	0%	4.4%	2.2%	18%	53.3%
	Cn2. I felt the learning process less monotonous and bulky while using the app.	4.4%	0%	2.2%	26.7%	66.7%
Identity	Id1. I felt absorbed and completely engaged while using the application.	0%	2.2%	4.4%	48.9%	44.4%
	Id2. The application somewhat helped me built my skills on manipulating safety equipment and performing safety procedures.	2.2%	4.4%	17.8%	18%	35.6%
Interaction	In1. The virtual buttons and image targets made me feel in control over my actions.	8.9%	2.2%	31.1%	44.4%	13.3%
	In2. I was not bothered by any interruptions such as error messages or irrelevant information.	48.9%	0%	13.3%	22.2%	15.6%
	In3. The use of a mobile application with the image targets and virtual buttons concept made the training more interactive.	2.2%	2.2%	2.2%	33.3%	60%
Collaboration	Cb1. I collaborated more with others while using the app (helping each other while using the app or discussing about how it works).	11.1%	31.1%	20%	20%	17.8%
Satisfaction	S1. Overall, I enjoyed the experience and felt happy and satisfied after using the app for EPT.	0%	2.2%	6.7%	33.3%	57.8%
	S2. I think the application could be a potential support to cabin crew during EPT.	0%	2.2%	4.4%	26.7%	66.7%
	S3. I may consider using the application again for EPT and personal review.	2.3%	0%	9.1%	31.8%	56.8%
	S4. I can recommend this app to my fellow cabin crew.	0%	4.4%	2.2%	26.7%	66.7%

According to a significant 46.4% of participants, a more practical approach within the aircraft is more appropriate for building skills on EPT and the AR tool is only relevant to the initial stages of the training process. From further analysis, it is found that SFPs mostly responded negatively or were neutral on this question. Usually having more than 25 years of experience in this field, it can be said that a mobile app might not built their skills further in this field.

5.6 Interaction

As for interaction, only 57.7% of participants felt in control over their actions by using virtual buttons and image targets. A significant 42.2% of participants perceived otherwise due to the first experience with virtual buttons where some assistance had to be provided in manipulating such control. Similarly, for In2, 48.9% of participants strongly disagreed about not to be bothered by any error messages or irrelevant information. This is because of some technical issues faced during the evaluation session where the shadow on the virtual button impacted interaction. Also, the phone was phone lagging and overheating due to prolonged use of camera and animations that added to the issues. However, even with the issues with In1 and In2, 83.3% of the participants found using AvGeek AR during EPT more interactive as compared to regular classroom sessions, thus implying that AR enhanced interactivity compared to traditional classroom training.

5.7 Collaboration

This attribute is mostly relevant for systems where multiple users are involved (e.g. games and billboards). However, since participants could interact with each other during use of the system, this attribute was also considered. Nevertheless, lower scores were obtained for this attribute. 42.2% of participants felt that they did not collaborate with the other cabin crew during the evaluation. This was mainly because the mobile app promoted individual use and participants had to focus on using AvGeek AR rather than working in groups to complete the tasks. Furthermore, AvGeek AR is found to lack some features where the cabin crew can share experience and interact more with the others. As such, only 37.8% believed they collaborated with the peers. Social interaction mostly took place when a participant could not understand about image targets to be used or about how to manipulate some virtual buttons.

5.8 Satisfaction

Satisfaction highlights the overall positive emotions such as happiness and enjoyment which may lead to positive engagement from users and the motivation to use the application, towards recommending others to use. 91.1 % felt happy and satisfied after using AvGeek AR while 86.6% of them claimed they will use the app again for EPT. As discussed earlier, some participants highlighted the lack of dynamic contents at every use thus preventing a full score from this item. Also, 93.4% of participants believed that this application can be recommended to other cabin crew members and the same number believed that AvGeek AR is a potential support to cabin crew during EPT.

6 Critical Analysis

Based on the results shown above, the mean scores for each PEEM construct was computed and are represented within the bar chart in **Error! Reference source not found.**. From the bar chart, it could be observed that Attention has the highest mean score of 4.7. This is mainly due to the user friendliness of the application which all the cabin crew agreed. The other factors contributing to the high mean score for this attribute are the appealing features such as 3D models, videos, images, virtual buttons which the cabin crew believed to have grabbed their attention. Similarly, relatively high means scores such as 4.5, 4.4 and 4.0 were obtained by the other attributes such as satisfaction, goals, content and concentration respectively. At the other end, collaboration is positioned last with a mean score of 3.0. As highlighted previously, this is because of the lack of collaborative features in the application and as such, the cabin crew felt the social connection only they were having issues with the application.

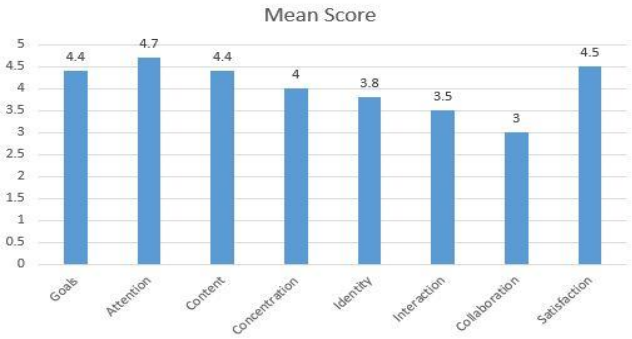


Figure 1: Mean Scores of the PEEM Attributes

Finally, in order to measure the overall engagement of Avgeek AR during the training, the PEEM matrix was applied to compute the net experience as explained earlier. In this endeavor, the mean scores of the measured items were summed to obtain the total score (84.65), which was divided by the number of attributes (8). A score of 10.58 was obtained for the net experience, which highlights a positive overall score. From literature, a comparative study of different AR applications revealed a median net experience score of 7.8, the lowest score as 7.2 and the highest as 11.33 [19]. As such, with

a score of 10.58 for Avgeek AR, which is above than the median net score and close to the highest score, it can be deduced that the app has evoked positive engagement among the users whereby satisfying the 8 driving forces of engagement [18,19]. This positive score also highlights that AR was found to enhance engagement during EPT and since motivation is derived from engagement, a positive engagement may result in enhancing the motivation of cabin crew during emergency procedures training. Even though an overall positive result was obtained, different limitations could undermine the findings revealed.

Firstly, demographic factors (e.g. age group, education level or computer literacy) can influence the results and studying such parameters was beyond the scope of this paper. Also, influences on learning and performance following training were not investigated. Finally, further scientific test could be performed to enhance the reliability of the collected data by performing tests such as independent T-Test or Wilcoxon signed-rank test. Assessing these factors can reveal insightful information on whether AR helps to improve knowledge acquisition process and help learners better perform during emergency events.

7 Conclusion and Future Works

This paper investigated whether augmented reality can effectively enhance user engagement during emergency procedures training in the context of aviation. Due to the lack of existing solutions, an AR-based application called AvGeek AR was developed using Unity and Vuforia for Emergency Procedures Training of the cabin crew members of national airline. The features of the application were designed taking into consideration factors to enhance motivation and engagement hence to remediate the problems faced during safety training. User engagement was then assessed using the Positive Engagement Evaluation Method involving 45 cabin crew members. Following evaluation, the net experience score obtained was 10.58, which highlights that AR can potentially improve user engagement during the emergency procedures training. However, results varied among the attributes of PEEM and the lowest score was achieved for collaboration and interaction thus implying that more efforts are needed to address these criteria when designing such types of systems. As future works, the limitations identified in this study need further attention. These include influences of demographic factors on user engagement when using such AR-based tool in addition to learning effectiveness and training performance during emergency events.

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