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A COMPARATIVE INVESTIGATION OF USABILITY ISSUES TOWARD VIRTUAL REALITY IMPLEMENTATION IN A STATE-OWNED SHIPPING SERVICE ENTERPRISE

Muhamad Fajar[1], Yogi Udjaja[1], David[1], Andry Chowanda[1,2]
Budi Juarto[1,2] and Yulianto[1,2]

[1]Computer Science Department, School of Computer Science
[2]Computer Science Department, BINUS Graduate Program – Master of Computer Science
Bina Nusantara University
Jl. K. H. Syahdan No. 9, Kemanggisan, Palmerah, Jakarta 11480, Indonesia
{ muhamad.fajar; david01; achowanda }@binus.edu
{ yogi.udjaja; budi.juarto; yulianto003 }@binus.ac.id

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Abstract. *The 404.50% work accidents increase has prompted a state-owned shipping service corporation to implement safety training using virtual reality technology. This study intends to identify usability issues in safety training using virtual reality before being implemented to the broader users. The evaluation uses a heuristic evaluation involving 18 respondents from various backgrounds, such as academicians, practitioners, and employees. During the use of VR respondents did not experience usability issues. Furthermore, the comparison evaluation reports the insignificant difference in usability based on respondents' experience with virtual reality with Sig. ($0.346 > 0.05$). Also, there is an insignificant difference based on respondent backgrounds between Academician and Practitioners with Sig. 2-tailed ($0.544 > 0.05$), Academician and Employee with Sig. 2-tailed ($0.937 > 0.05$), Employee and Practitioners with Sig. 2-tailed ($0.753 > 0.05$).*
Keywords: Virtual reality, Safety training, Usability, Heuristic evaluation

1. **Introduction.** During the familiarization and safety training in a vessel, there are various problems or limitations when conducting training [1,2]. These limitations include the time of each trainer and personnel, the vessel location, and the safety equipment for all participants when conducting in a real vessel that requires costs [1,3]. In addition, the simulation of unsafe conditions has a high level of risk, such as a fire in a ship, which is also dangerous for ordinary people who have never experienced a fire situation before [1,4,5] and essential to see the readiness of the ship's crew in dealing with various kinds of dangerous situations such as fires on board so that each individual knows what to do in a difficult situation and how to coordinate with other crews in a hazardous case [1]. Security handling is also carried out by [6] that is applied to the spacecraft terminal to improve process safety rendezvous and docking. Virtual Reality (VR) in the shipping industry has been carried out on Panama bulk cargo ships in China [5]. This includes several strategic locations on the ship, such as fire control rooms, fire-fighting equipment, and carbon dioxide rooms [5]. Research conducted by Wu et al. in 2019 also implemented VR in ship fire fighting training in the context of safety training with fire handling cases [1].

PT Pertamina is a state-owned enterprise fastened in oil and gas business activities in Indonesia [7]. PT Pertamina Trans Kontinental (PTK) is a subsidiary of PT Pertamina (Persero) which is engaged in the shipping service industry with the function of providing total support to PT Pertamina (Persero) such as procurement of fuel distribution, procurement of maritime transportation, and becomes general agent and handling agent [8]. From 2017 to 2019, there was an increase in work accident cases due to unsafe acts and

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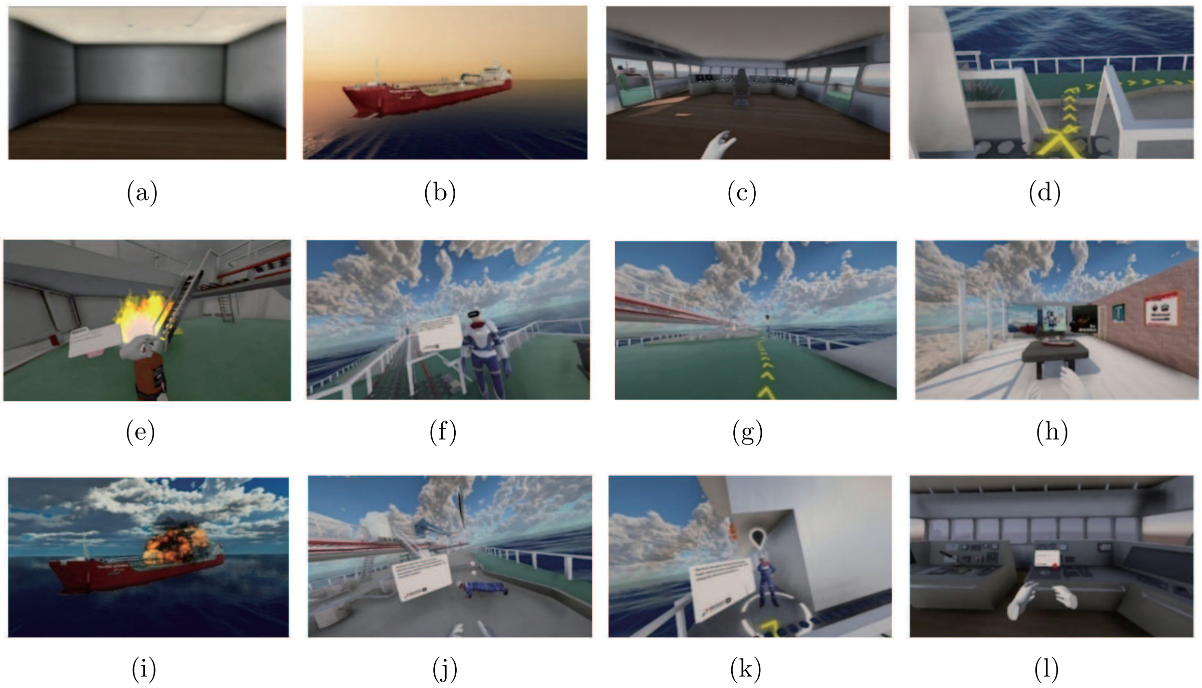
conditions from 111 to 560 [8]. There was an increase in work accidents due to unsafe acts and condition cases by 404.50% from 2017 [8]. One way to reduce work accidents due to unsafe acts or work accidents caused by humans is to conduct safety training [9]. PT Pertamina (Persero) has been committed to starting various implementations of technology digitalization at Pertamina, following the company's vision [10]. The form of this commitment is implemented by implementing safety training using virtual reality technology. Recent research reveals the effectiveness of the implementation of safety training using virtual reality technology [11]. The use of virtual reality can also reduce costs and time because users do not need to be present on the ship in person, and reduce the risk of unnecessary accidents simulation training [1]. Figure 1 displays the implementation of safety training in a virtual reality application developed by PTK called PTK Virtual Reality Application (PTK VR APP). Before being distributed to a broad user, the measurement of success rate was carried out by an initial usability evaluation of the PTK VR APP. Usability evaluation was conducted to find weaknesses in the application in order that system improvements can be executed before release [12]. Usability evaluation on safety training applications that use virtual reality has been carried out in order to reduce user discomfort in the future [13]. Hence, usability evaluation explores user limitations in using virtual reality applications. Therefore, the developers can improve user interaction and perception in the future [14]. Zhang et al. conducted a usability test on eight respondents who revealed that the use of VR was better in terms of accessibility, learning efficiency, and mobility than traditional desktop [13]. Several studies conducted usability measurements using the heuristic evaluation method in order to evaluate and map usability issues [15-17]. Heuristic evaluation was also carried out by Jeddi et al. toward the national health information system with five respondents to assess the system interface,



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l)

Figure 1. (a) Natural engagement, (b) compatibility with the user task and domain, (c) the natural expression of action, (d) close coordination of action and representation, (e) realistic feedback, (f) faithful viewpoint, (g) navigations and orientation support, (h) a straightforward entry and exit point, (i) consistent departures, (j) learning support, (k) clear turn-taking, and (l) the sense of presence

which found > 50% of major usability issues [16]. In another study, heuristic evaluation was also able to map usability issues on community sharing platform applications and yoga support applications by involving several respondents from various backgrounds [18,19]. In virtual reality apps, Oliveira et al. described the use of heuristic evaluation in the "Supernatural: the origin" application [17]. The result is that the heuristic evaluation is able to overcome the usability issue, with 22% of evaluators obliged to have usability issues on the natural engagement [17]. Furthermore, heuristic evaluation was able to be used for comparison purposes in multiple configurations like Madathil and Greenstein, who reported that there was an insignificant usability difference in different scenarios [20]. The contribution given in this study is to conduct usability testing of VR applications on work safety at PT Pertamina Trans Kontinental (PTK) using heuristic evaluation. The results to be achieved from this study are to compare whether there are significant differences in the use of VR in work safety from 3 groups, namely Academicians, Practitioners, and also Employees and also from two groups based on experience, namely those who have used VR and have never used VR.

This research contains 4 sections. Section 1 explains about research problems, the application of virtual reality technology to work safety abroad, explanations about PT Pertamina Trans Kontinental (PTK), the problems experienced before applying virtual reality technology and a literature study on virtual reality is conducted on safety training and heuristic evaluation. Section 2 describes the heuristic evaluation used in this study. Section 3 explains the results and evaluations, including heuristic evaluation result, comparison between users based on their experience with virtual reality, comparison between users based on background. Finally, in Section 4, the main findings of the research will be summarized.

2. **Method.** PTK virtual reality application testing is carried out to determine the level of usability using heuristic evaluation. Sutcliffe and Gault proposed a heuristic evaluation technique for virtual reality consisting of 12 variables [21]. The evaluators assess and categorized usability issues based on heuristic evaluation variables toward five interpretation scale with interval range: destructive usability issues (0-0.80 points), major usability issues (0.81-1.60 point), minor usability issues (1.61-2.40 points), cosmetic usability issues (2.41-3.20 points) and the absence of usability issues (3.21-4.00 points) [16,22,23].

The evaluators were asked to use and complete each task in PTK VR APP. Then, they were asked to assess each heuristic evaluation variable statement based on five interpretation scales and provide a commentary as optionally. The assessments from evaluators are accumulated on average to obtain conclusions from each aspect of the heuristic evaluation. Then, we conduct a comparison in two parts – the first comparison of evaluators who have experienced in using VR and the evaluators that never tried VR before; the second performs a comparison to see if there is a difference based on the background of the evaluators. The comparison approach is conducted to investigate if there is a significant difference in usability issues based on evaluators background. Then, the comparison is also conducted based on their experience with virtual reality to recognize whether the usability issue is significantly different or not particularly in virtual reality for safety training.

Respondents of testing evaluation involve 18 evaluators consisting of various backgrounds such as academicians who have background as master's degree, practitioners who have backgrounds as programmers or multimedia designers, and employee that only has a background as an employee of PTK. The evaluator is separated into six groups, where group 1 and group 2 have master's degree (Academician), group 3 and group 4 are practitioners in the field of computer science (Practitioners), and then group 5 and group 6 are employees of PTK (employee). Each group consisted of 3 respondents who were evaluated in different timescales. We also separated them based on their experience with VR. The users of groups 1, 3, and 5 who never tried virtual reality called Group A. Meanwhile, groups 2, 4, and 6 have experienced playing or trying VR called Group B.

3. **Results and Analysis.** All tabulated data values present in an average of each group per heuristic evaluation variables. Furthermore, we present the accumulated average and standard deviation based on the evaluator's experience with VR (See Table 1). Then, we also present the average and standard deviation data based on the evaluator's background (See Table 2). We will discuss each heuristic evaluation variable based on the overall average of all evaluators and perform the two-part comparisons mentioned earlier.

TABLE 1. Result scores

		Backgrounds	Evaluation heuristic variables											
			A	B	C	D	E	F	G	H	I	J	K	L
Group A	Group 1	Academician	3.67	3.67	4.00	3.33	3.67	3.67	4.00	3.67	3.33	4.00	4.00	4.00
	Group 3	Practioners	3.33	3.67	2.67	3.67	**3.00**	4.00	3.67	**3.00**	3.33	3.67	3.67	2.33
	Group 5	Employee	3.33	4.00	3.00	4.00	4.00	3.67	4.00	3.67	3.67	3.67	3.67	3.33
	Group A Mean		3.443	3.78	3.223	3.67	3.56	3.78	3.89	3.45	3.44	3.78	3.78	3.22
	Group A SD		0.16	0.16	0.565	0.27	0.42	0.16	0.16	0.32	0.16	0.16	0.16	0.69
Group B	Group 2	Academician	4.00	4.00	2.33	4.00	3.67	4.00	3.67	4.00	4.00	3.67	3.67	3.00
	Group 4	Practioners	3.67	3.67	3.67	3.67	3.67	3.67	3.67	4.00	3.67	4.00	4.00	3.67
	Group 6	Employee	3.67	3.67	3.33	3.33	3.67	3.67	3.67	3.67	3.67	3.33	3.67	3.67
	Group B Mean		3.78	3.78	3.11	3.67	3.67	3.78	3.67	3.89	3.78	3.67	3.78	3.45
	Group B SD		0.16	0.16	0.57	0.27	0	0.16	0	0.16	0.16	0.27	0.16	0.32
Group A and Group B Mean			3.61	3.78	3.17	3.67	3.61	3.78	3.78	3.67	3.61	3.72	3.78	3.33
Group A and Group B SD			0.23	0.16	0.57	0.27	0.30	0.16	0.16	0.33	0.23	0.23	0.16	0.55

TABLE 2. Result scores categorized by backgrounds

		Evaluation heuristic variable											
		A	B	C	D	E	F	G	H	I	J	K	L
Academician	Mean	3.84	3.84	3.17	3.67	3.67	3.84	3.84	3.84	3.67	3.84	3.84	3.50
	SD	0.17	0.17	0.83	0.33	0	0.17	0.17	0.17	0.33	0.17	0.17	0.50
Practioners	Mean	3.50	3.67	3.17	3.67	3.34	3.84	3.67	3.50	3.50	3.84	3.84	**3.00**
	SD	0.17	0	0.50	0	0.33	0.17	0	0.50	0.17	0.17	0.17	0.67
Employee	Mean	3.50	3.84	3.17	3.67	3.84	3.67	3.84	3.67	3.67	3.50	3.67	3.50
	SD	0.17	0.17	0.17	0.33	0.17	0	0.17	0	0	0.17	0	0.17

3.1. **Heuristic evaluation result.** Data analysis was carried out to obtain the average score of each evaluator from all of their respective backgrounds. The results from Table 1 are as follows.

- Natural engagement (A) gets an average level of 3.61 with the quality of the application making the user feel the situation like being on a ship, and the level of accuracy of the resemblance to the ship resembles the original. However, there is a respondent who has a low average score because some parts of the model and texture are still not optimal (See Figure 1(a)).
- Compatibility with the user task and domain (B) at the level of 3.78 with the level of similarity expected by the evaluator with employee backgrounds. That also indicates the evaluator with employee background reaching the highest point 3.84 (See Table 2) and mentions the virtual environment with almost perfect atmosphere objects (See Figure 1(b)).
- The natural expression of action (C) is at point 3.17, which interprets as a cosmetic usability problem. Several evaluators who have experienced virtual reality (Group B) revealed that exploring the virtual environment, such as inside a vessel room, was too fast for a human walking and unrealistic (See Figure 1(c)).

- Close coordination of action and representation (D). Some evaluators reveal the action of going down the stairs in a virtual environment feels a bit dizzy (See Figure 1(d)). This is because the evaluator believed cylinder eye disease factor. However, the response time movement in the virtual environment and real-world good enough within general indicates the absence of usability issue with an average of 3.67 points.
- Realistic feedback (E) got an average point of 3.61 and interpreted the absence of usability issues. The PTK VR APP applies the laws of physics like when fire fighting cases (See Figure 1(e)). Also, several evaluators suggest fire fighting cases can be optimized with adjustment of the area or location.
- Faithful viewpoint (F). The visual representation in a virtual environment is similar to the point of view in the actual situation (See Figure 1(f)). The average point of the faithful viewpoint is 3.78 which indicates the absence of usability issues.
- Navigations and orientation support (G). The evaluators reveal their position in the virtual environment considering guidance features like the direction interface (See Figure 1(g)). This variable indicates the absence of usability issues in the average score of 3.78.
- The clear entry and the exit point (H) well communicated through the menu button can be improved by touching the user experience on the button. This also reveals the absence of usability issues with an average point of 3.67 (See Figure 1(h)).
- Consistent departures (I) indicate the absence of usability issues with a total average of 3.61. Evaluators reveal the consistency of environment design in realistic designs such as explosions, atmosphere, and the vessel (See Figure 1(i)).
- Learning support (J). The evaluators agreed on PTK VR APP very proper by providing clear explanations like user interface and visuals character that can be easy to understand (See Figure 1(j)). The PTK VR APP indicates support for learning in the absence of usability issues with an average of 3.72 points.
- Clear turn-taking (K). The evaluator reveals the use of user interfaces (UI) as a clear sign when the system initiates something, for example, initiates the animation of a character performing an unsafe act such as smoking (See Figure 1(k)). The overall value is 3.78 point, which means the absence of usability issue in this variable.
- The sense of presence (L) aspect had an average point of 3.33 points that indicates the absence of usability issues. The evaluators reveal they felt involved in the entire virtual environment, such as interacting with the engine on the vessel (See Figure 1(l)).

Furthermore, we marked the results of the assessment that interpreted the cosmetic usability issue on realistic feedback (E) and the clear entry and the exit point (H) variable according to evaluators who had never tried virtual reality (Group A) that had a background as Practitioners (See Table 1). Generally, they reveal PTK VR APP could perform some improvements to the realistic feedback (E) with additional visual effects such as fire splash (See Figure 1(e)) and could add animate user interface in clear entry and exit point (H) (See Figure 1(h)). Moreover, we highlight the evaluators had practitioners background from Group A and Group B that indicates the sense of presence (L) as a cosmetic problem with an average point of 3.00 in this variable (See Table 2). They reveal that the 3D assets on the vessel interior can still be improved, such as optimizing mesh and texture for improvement of the sense of presence (L) in general (See Figure 1(l)). Overall, the natural expression of action (C) variable is the only one classified as cosmetic usability issues based on all evaluators' assessments with an average point of 3.17 (See Table 1). Several evaluators who experienced in trying virtual reality technology (Group B) mentioned that the experience of walking in a virtual environment felt less natural because it was too fast. Previous research has revealed that cosmetic usability issues do not need to be fixed unless there is a release deadline or have more additional time [18,22].

3.2. **Comparison between users based on their experience with virtual reality.** The mean value of each variable in the group based on their background is taken to represent the group based on their previous experience with virtual reality for comparative testing. Table 3 demonstrates the comparison of the results. The results of the T-test indicate that the data is homogeneous, or it can be concluded that the data is considered come from a normal distribution (Sig. = 0.533, Sig. > 0.05), and in the equal variance assumed section it is known that Sig. (2-tailed) of 0.346 (Sig. (2-tailed) > 0.05), demonstrated that there is an insignificant difference between Group A and Group B. It means there is no difference in the usability issue of users who have experienced in using VR or not. Furthermore, this section indicates that the experiences of respondents do not influence usability issues, which means inexperienced respondents are not different from experienced respondents.

TABLE 3. T-test result

<table>
<tr><td colspan="2" rowspan="4"></td><td colspan="10">Independent samples test</td></tr>
<tr><td colspan="2">Levene's test for equality of variances</td><td colspan="8">T-test for equality of means</td></tr>
<tr><td rowspan="2">F</td><td rowspan="2">Sig.</td><td rowspan="2">t</td><td rowspan="2">df</td><td rowspan="2">Sig. (2-tailed)</td><td rowspan="2">Mean difference</td><td rowspan="2">Std. error difference</td><td colspan="2">95% confidence interval of the difference</td></tr>
<tr><td>Lower</td><td>Upper</td></tr>
<tr><td rowspan="2">Score</td><td>Equal variances assumed</td><td>.405</td><td>.533</td><td>−.970</td><td>16</td><td>.346</td><td>−.10111</td><td>.10424</td><td>−.32208</td><td>.11986</td></tr>
<tr><td>Equal variances not assumed</td><td></td><td></td><td>−.970</td><td>15.966</td><td>.347</td><td>−.10111</td><td>.10424</td><td>−.32212</td><td>.11990</td></tr>
</table>

3.3. **Comparison between users based on background.** After conducting the T-test, this study also looks at how to do the comparison of each background of respondents that are divided into three categories: Academician (Group 1 and Group 2), Practitioners (Group 3 and Group 4), and Employee (Group 5 and Group 6). Comparison uses one-way ANOVA in looking at multiple comparisons to see whether three or more averages differ significantly or not. The result shows that Sig. = 0.544 (Sig. > 0.05), indicates the comparison based on participants with the academic background (Academician) does not have a significant difference with Practitioners. Also, there is an insignificant difference between Academician and Employee with Sig. (0.937 > 0.05), see Table 4. Moreover, the results show there is an insignificant difference in usability issues between Practitioners and Employees with Sig. (0.753 > 0.05). This section proves Academician, Practitioners and Employees usability issues have no difference, meaning that it can also be said that there is no influence between respondent's background with their assessment of usability issues.

4. **Conclusion and Discussion.** The overall result has shown PTK VR APP does not have usability issues unless on the natural expression of action (C) that indicates PTK VR APP is proper to be implemented for safety training to broader users. Even though the issue does not need to fix unless having the additional time or not pursued by the deadline. Furthermore, it is necessary to consider the insight from the evaluators that have experienced using VR (Group B) to adjust the speed of walking in the virtual environment for solving cosmetic usability issues. The investigation also showed insignificant usability issues between the evaluator's background and their experience with VR. Although there are still limited respondents, the research has been carried out looking at

Table 4. The one-way ANOVA tabulation

Multiple comparisons						
(I) Background	(J) Background	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Academician	Practitioners	.11000	.10315	.544	−.1476	.3676
	Employee	.03556	.10315	.937	−.2220	.2932
Practitioners	Academician	−.11000	.10315	.544	−.3676	.1476
	Employee	−.07444	.10315	.753	−.3320	.1832
Employee	Academician	−.03556	.10315	.937	−.2932	.2220
	Practitioners	.07444	.10315	.753	−.1832	.3320

the diversity of respondent backgrounds. Also, this research can be referenced to examine the usability issues of VR applications in industries similar to PT Pertamina Trans Kontinental, especially in safety training purposes. In the future, further research will further examine how the knowledge level of users is to see the impact of using virtual reality-based applications in similar cases.

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