Eye tracking analysis of airport flight information display system (FIDS) to improve the information search efficiency

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Abstract. Air transportation is one mode of transport with a large economic contribution to Indonesia (38,12%). The airport must ensure to provide the best service, especially the efficiency of information given. Flight Information Display System (FIDS) is one substantial information system in the airport and aims to increase communication efficiency about the flight information. Based on the preliminary research, the airport’s FIDS showed different visual design one to another. Therefore, this research aims to analyze it to improve information search efficiency. The research used full factorial design as the experimental design method, eye tracker as the data gathering, and mixed-design ANOVA with post hoc test as the data analysis. We involved 3 factors that have a strong correlation with FIDS searching time efficiency: color combination of background and text, row arrangement, and column arrangement. As the measure, time to first fixation and total fixation used to indicate the information search efficiency. Data analysis generated 2 variables that improved information search efficiency on both data, except the row arrangement (only on Total Fixation data). The intended variable levels are dark color background and light color text, row arrangement based on the alphabetic order of the “Flight” column, and column arrangement “Flight-Time-Destination”.

1. Introduction

The transportation sector is the main key in providing human mobility. The growth of this sector was predicted to rise as 11,15% in 2019. According to the Supply Chain Indonesia study, air transportation was in second place in contributing to Indonesia’s economic growth with a 38,12% contribution [1]. PT Angkasa Pura I and PT Angkasa Pura II as the air transportation operator in Indonesia reported that the amount of flight departure and passengers within 2015-2019 increased year after year [2]. The International Air Transport Association (IATA) forecasted and analyzed that the total passengers would increase double to 7 billion in 2034 with average annual growth in demand (start from 2014) [3]. There are several benefits in traveling by air such as: (1) get social on a plane, (2) small accident rate (0,01%), (3) fastest transportation, (4) no country boundaries, and (5) comfortable and less workload [4]. Regulation of Ministry of Transportation Indonesia number 77 of 2015 contains a general standard in governing the airport. Flight Information Display System (FIDS) is one of the information systems that is required to be installed at the airport. The purpose of the device is to increase communication and ensure all the passengers getting the appropriate status about their flight [5]. The device plays an important role for the passenger to get the flight information as soon as possible.
Based on the literature review and direct observation of the FIDS visual display design, there is no general standard or regulation of displaying the FIDS on each airport. Some FIDS devices provided different visual display (color combination of background and text, information arrangement, font, size, and many more) even though the device represented the same information, such as airline logos, number of flights, destinations, flight departure time, and status or remark of the flight. Based on the fact that there are so many FIDS design to display the same information, we intended to analyze the best visual display configuration that generates the best information searching efficiency for the passenger. We used the information searching efficiency as the performance measure because it is aligned with the main purpose of FIDS.

Despite there is much visual display research, there is no previous research on the visual display of the FIDS to date. The previous FIDS research discussed some other aspects, such as the component system, the programming language, or the energy in operating an information display system. There was research that studied system design components in displaying an information system for train traffic control called the STEG system [6]. In other cases, there was a research that examined renewable energy usage in FIDS device and published as “Solar Powered Passenger Information Display System”. Therefore, the study of the FIDS device is very essential to improve the airport system efficiency that brings a positive experience to the passenger [7].

Based on the result of interviewing some passengers randomly in some airports, they affirmed several problems related to FIDS visual display design. First, they stated the font size of the device, and sometimes space between lines was small. This improper spacing set caused some passengers should reread about the flight information status. There was also another problem identified like a monotonous color combination of background and text and difficult to find the device. Depend on those discovered facts, designing the FIDS device is important. A way to get the ideal FIDS device is by considering the ergonomic aspect, precisely on the arrangement of the visual display device. International Ergonomics Association defined Ergonomic as the scientific discipline concerned with the understanding of interactions among humans and other elements of the system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance [8].

There were 3 independent variables were confirmed to have effect indication against the information search efficiency of the FIDS device in this study. The first independent variable was a color combination of background and text. The contrast of the combination color of background and text would increase legibility and readability [9]. The second and third independent variables were confirmed based on preliminary research using Tobii Pro Glasses 2 Wearable Eye Tracker. We made some FIDS configurations with different variables then analyze the information search performance from a small group of participants. The result of the preliminary research indicated that the FIDS configurations with different row and column arrangement have different performance on information search efficiency. Therefore, the second and third independent variables were row arrangement and column arrangement. We also used eight control variables, such as the age of the participant, display size, display font type, display font size, display visibility, display brightness, lighting exposure, and noise level.

This research aims to figure out the best FIDS visual display configuration based on the predetermined variables to improve the information search efficiency. This research was expected to improve the FIDS device in each location of all airports so that it would be more appropriate with the passenger behavior and more efficient to use.

2. Method
This research used an experimental factorial design concept for illustrating the study. Factorial design as a part of experimental design means all the interaction levels of variables were tested. The levels of each variable are different. For the first independent variable, there are two levels of color combination of background and text. The first one is a blue color background - white color text. Based on the preliminary research held, this level of combination color background and text is the most applicable. Another level of this variable is a combination of blue color background - white color text and white
color background - black color text. Addition of white color background - black color text in this level because it was said that optimal legibility will be accomplished by a combination color with high contrast, such as black and white [10][11].

For the row arrangement variable, the levels are row arrangement based on time order from the “Time” column and based on alphabetic from the “Flight” column. Determination of row arrangement based on time order from the “Time” column because all FIDS devices found applying this level variable whereas for alphabetic order from the “Flight” column was chosen since it is another common row arrangement in displaying in a format table. This level also generates the group of the same flight logos in sequence. Furthermore, levels of column arrangement variable are based on initial data that showed “Flight” column and “Destination” column are column which contains the first fixation. Table 1 represents the factorial design of the study.

| Color Combination | Row Arrangement | Column Arrangement |
|-------------------|-----------------|--------------------|
| Dark color background (dark blue color) and light color text (white color). | Based on the alphabetic order of the “Flight” column | Flight-Destination-Time |
| Light color background (white color) and dark color text (black color). | Based on time order of “Time” column | Flight-Destination-Time |

Participants were assigned in this study by applying a mixed subject experimental design that is a combination of within-subject and between-subject design. The mixed subject design used to avoid within or between subject disadvantages such as the presence of practice effect, large data variability, and the need for enormous participants to be involved. Each participant was randomly assigned to one level of the color combination background and text which is each participant will be given 8 treatments or interaction between 1 level of color combinations background and text with other variables.

Eye tracker used to capture the eye movement of the user. Eye movement was declared able to be additional data that depicts the human cognitive process [12]. The eye tracker is also defined as one of the powerful devices in collecting, analyzing, and visualizing eye movement data for visual display arrangement [13]. Therefore, the eye tracker device was chosen as the measurement tool for improving information search efficiency on the FIDS device.

2.1. Participants
Overall, 70 participants were involved in this study. Participants should have experience in being the passenger of air transportation. All participants should also have a normal 20/20 until 20/40 visual acuity. Visual acuity 20/40 is estimated the same as 0.75 rate of myopia eye disorder [14], but there is
another researcher estimated it as 1 scale of myopia eye disorder [15]. Then, this study used scale 1 of myopia eye disorder as the maximum barrier of selecting participants.

The amount of the participants considered Cochran Formula. In that formula, we first defined the confidence level and precision of the data. By 95% confidence level and 0.5-1 approximation of the precision data, both of the data (Time to First Fixation and Total Fixation) required less than the number of participants had been obtained. The age range of the participants was 17-47 years old.

2.2. Procedures
The experiment was held in the ergonomic laboratory of Parahyangan Catholic University. It has taken 20-25 minutes for each participant. The data gathering used a wearable eye tracker device to capture the data, 43 inch TV to display the FIDS, a laptop to track the eye tracker recording, and a speaker to maintain the noise level. First of all, we explained the given task and the use of the eye tracker to participants. Then, we made the distance between the participant and 43 inch TV as 2,4 meters as the normal reading distance and connect the eye tracker with the recording software called Tobii Pro Glasses Controller. Each participant got 8 boarding pass packages, which each package contained 3 pages of the different boarding pass. Participants had to find a flight status of every boarding pass page they faced. We had recorded the participant’s eye movement until they finished all tasks given.

2.3. Measure
There were 2 types of data used in this study in representing FIDS device with information search efficiency, i.e. time to first fixation (TTFF) and fixation number. Efficiency in this study means the process with a minimum of time, workload, and cost. In this case, time to first fixation can represent minimum time and the fixation number represents minimum workload. Time to first fixation is described as the length of time each participant in entering the intended area of interest for the first time [16]. Another time to first fixation definition is this kind of data able to indicate how the stimulus of the area interest will attract the attention participants [17]. Flight status or remark was the area of interest. It will communicate the readability and efficiency time of every FIDS device prototype.

Similar to the previous one, the fixation number records the amount of participant’s eye movement until reaches the area of interest for the first time. Fixation number in searching for the information indicating reading uncertainty [18]. The higher fixation number gives 2 side perceptions: (1) there’s some part of the stimulus got participant’s attention and (2) complicated stimulus leads participants to repeat their eye and caused a longer time [19]. Both of the time to first fixation and fixation number derive from participant’s recording.

3. Result
After gathering “Time to First Fixation” and “Total Fixation” data, assumptions of ANOVA will be tested first. All the classic assumptions of ANOVA should be fulfilled before doing mixed-design ANOVA. The ANOVA aimed to show which variable in this study affects improving information search efficiency. After that, post hoc analysis was used to analyze the specific level of each variable that resulted in the best performance.

3.1. Data Gathering Process
The eye tracker recorded participant eye movement data during the experimental condition. Then, the record processed using Tobii Pro Lab as the analyzing software to produce each type of data. As mentioned before, “Time to First Fixation” data pointed out the area of interest that had to be defined before. In Tobii Pro Lab software, we had to select the intended flight status area so that the software would catch the exact time needed for the participant to reach their intended flight status. Moreover, we also had to match the recording video with the prototype of the FIDS visual display. After that, we sum up the “Total Fixation” data manually. Each treatment of the FIDS device display has 3 flight statuses to find by each participant. The replication would be calculated as the average time of getting flight status on each FIDS device prototype. The replication was aimed to remove the effect of the answer
position on time to the first fixation because we placed each answer randomly at the top, middle, and bottom of the display vertically.

3.2. Mixed Design Analysis of Variance (ANOVA)

The first assumption of doing ANOVA test is the population of data in which samples are drawn should be normally distributed. Saphiro-Wilk test was chosen to test this first assumption. Further, the second assumption is homogeneity variances between each treatment, tested by Levene’s test. Then, for the last is the independence of data which is presented by a scatter plot. All the assumptions were fulfilled in this study.

After accomplishing all the assumptions, we continued the processing data with mixed-design ANOVA. This kind of ANOVA was intended for the study that used mixed design subjects. In that ANOVA test, the first table conducted was descriptive statistics. On a descriptive statistic table, we could see the average and standard deviation value of each treatment. Afterward, another table shown is the test of within-subjects and between-subject effects of both data. By the test of within-subject effects, we could discover factor or interaction factors that part of within factors of the study which affects improving information search efficiency to participants as representative of airport passengers. Table 2 represents an example of the test of within-subject effects of “Time to First Fixation” data for the row arrangement variable.

Table 2. Within-subject effects test example of “time to first fixation” for row arrangement

| Source                          | df | Mean Squares | F    | Sig. | Partial Eta Squared |
|---------------------------------|----|--------------|------|------|---------------------|
| Row arrangement                 |    |              |      |      |                     |
| Sphericity Assumed              | 1  | 8,986        | 2,264| 0,137| 0,032               |
| Greenhouse-Geisser              | 1  | 8,986        | 2,264| 0,137| 0,032               |
| Huynh-Feldt                    | 1  | 8,986        | 2,264| 0,137| 0,032               |
| Lower-bound                    | 1  | 8,986        | 2,264| 0,137| 0,032               |
| Row arrangement                 |    |              |      |      |                     |
| * Color combination of          |    |              |      |      |                     |
| background and text             |    |              |      |      |                     |
| Sphericity Assumed              | 1  | 30,331       | 7,643| 0,007| 0,101               |
| Greenhouse-Geisser              | 1  | 30,331       | 7,643| 0,007| 0,101               |
| Huynh-Feldt                    | 1  | 30,331       | 7,643| 0,007| 0,101               |
| Lower-bound                    | 1  | 30,331       | 7,643| 0,007| 0,101               |

The example of the test of within-subjects effects table above concluded the row arrangement as the within factor with no correlation with improving information search efficiency. This conclusion is based on the value of the “Sig” column that has a value lower than 0.05 (alpha value). However, the value of the “Sig” column has value more than 0,05, it would be said that the factor or interaction has an effect on improving information search efficiency. From Table 2, we can conclude that the interaction factor of row arrangement and color combination of background and text has an effect of improving information search efficiency.

The table of between-subject effect also has been involved because this table could discover whether the between factors of study is has an effect of improving information search efficiency at the FIDS device. Between the factors of this study is the color combination of background and text. The definition of between factors with an effect on improving information search efficiency is the same with the previous test of within-subjects effects table, i.e. having a value of the “Sig” column lower than 0,05. Table 3 represents an example of the test of within-subject effects of “Time to First Fixation” data for color combination variables.

Table 3. Between subject effects test example of “time to first fixation” for colour combination

| Source               | df | Mean Square | F       | Sig. | Partial Eta Squared |
|----------------------|----|-------------|---------|------|---------------------|
| Intercept            | 1  | 2883,501    | 2244,100| 0,000| 0,971               |
| Colour Combination   | 1  | 33,265      | 25,889  | 0,000| 0,276               |
| Error                | 68 | 1,285       |         |      |                     |
By the example of Table 3, we got a conclusion that between factors of the study (the color combination of background and text) affects improving information search efficiency. It was shown by the 0 value of the ‘Sig’ column. Therefore, the color combination of background and text is one of the factors that have an effect on this study. This step was also completed of “Total Fixation” data. Table 4 represents the result of the factor and interaction factor in each type of data which has an effect of information search efficiency.

Table 4. ANOVA test summary of “time to first fixation” and “total fixation”

| Number | Level Factor/ Interaction Factor | Time to First Fixation | Total Fixation |
|--------|----------------------------------|------------------------|----------------|
| 1      | Interaction of row arrangement-combination color of background and text | Row arrangement | Interaction of row arrangement-combination color of background and text |
| 2      | Column arrangement                |                        | Column arrangement |
| 3      | Interaction of row arrangement-column arrangement |                        | Interaction of row arrangement-column arrangement |
| 4      | Combination color of background and text |                        | Combination color of background and text |
| 5      | -                                 |                        | |

3.3. Post Hoc Analysis
The post hoc analysis aims to discover the level of factor or interaction factor that had been founded before in mixed-design ANOVA. The test was named the Tukey HSD test. This would compare the contrast value (difference value each level factor). If the contrast value is smaller than the Tukey HSD test value, it would be concluded that the level of those factors has significantly different from other levels. Both “Time to First Fixation” and “Total Fixation” data showed a similar result of level factors and interaction factors. Table 5 represents the result of the post hoc analysis of both types of data.

Table 5 Post hoc analysis result of “time to first fixation” and “total fixation”

| Number | Level Factor/ Interaction Factor | Time to First Fixation | Total Fixation |
|--------|----------------------------------|------------------------|----------------|
| 1      | Row arrangement based on the alphabetic order of “Flight” column - Dark color text (dark blue color) and light color text (white color) | Row arrangement based on the alphabetic order of “Flight” column | Row arrangement based on the alphabetic order of “Flight” column - Dark color text (dark blue color) and light color text (white color) |
| 2      | Column arrangement Flight-Time-Destination | Row arrangement based on the alphabetic order of “Flight” column - Dark color text (dark blue color) and light color text (white color). | Row arrangement based on the alphabetic order of “Flight” column - Dark color text (dark blue color) and light color text (white color). |
| 3      | Row arrangement based on the alphabetic order of “Flight” column - Column arrangement Flight-Time-Destination | Column arrangement Flight-Time-Destination | Column arrangement Flight-Time-Destination |
| 4      | Dark color background (dark blue color) and light color text (white color) | Row arrangement based on the alphabetic order of “Flight” column - Column arrangement Flight-Time-Destination | Dark color background (dark blue color) and light color text (white color) |
| 5      | -                                 |                        | |

Based on the analysis, this study generated each level of 2 factors that proved in giving an effect on information search efficiency. For the color combination of background and text factor, the selected
level factor is a dark color background (dark blue color) and light color text (white color) while the selected level of column arrangement is the “Flight-Time-Destination” arrangement. However, the selected level for row arrangement was just approved in “Total Fixation” ANOVA and post hoc measurement. The level of the row arrangement is based on the alphabetic order of the “Flight” column. Figure 1 shows the result of each level factor to be implemented on the FIDS device.

Figure 1. Mixed-design ANOVA and post-hoc analysis result

4. Conclusion
According to mixed-design ANOVA and post hoc analysis results, the selected color combination of background and text is a dark color background (dark blue color) and light color text (white color). It is supported by the fact that blue color is the most recommended color for display, meanwhile color with high brightness and saturations for the text [20]. There is also another reason for another level color combination of background and text isn’t selected, the use of more than 1 color combination leads both of the color combination not having high contrast levels when they are combined.

For the row arrangement factor, the selected level is row arrangement based on the alphabetic order of the “Flight” column. This level factor sense to be the best one since this level arrangement is the best row arrangement when someone already knows what they are searching for, in this case, is flight number as the part with the highest fixation [21]. Every flight has their flight number which is issued by the International Air Transport Association (IATA). So, row arrangement based on the alphabetic order of the “Flight” column will help passengers find out their flight status using reliable information (flight number). And for the last factor, the level of column arrangement is “Flight-Time-Destination” for the first 3 columns. These 3 first columns are appropriate with the Z reading pattern as the most suitable display design that not only focuses on the text [22]. The “Time” column as the second column allows participant eye movement rapidly or it is called a saccade. The average amount of character that usually being ignored in saccade is 7-9 characters [23]. Then, participant eye movement will go to the next column i.e. “Destination” column. All participants also showed that the “Destination” column was the second column with the highest fixation and appropriate with the Z reading pattern. Therefore, all the factors in this design proved to affects improving information search efficiency. Future research should identify further variable has an effect of achieving the FIDS device objectives.
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