Ergonomic Design of Target Symbols for Fighter Aircraft Cockpit Displays Based on Usability Evaluation

Sung-Ho Kim[1], Woo-Seok Jang[1], Heung-Seob Kim[1], Hyoung-Seog Chung[2], Yong-Duk Kim[3], Woo-Jin Lee[3], and Hyeon-Ju Seol[4(✉)]

[1] Department of Systems Engineering, Air Force Academy, Cheongju, South Korea
{dilemma37,himono0219,afrotc02}@naver.com

[2] Department of Aerospace Engineering, Air Force Academy, Cheongju, South Korea
kafachung@gmail.com

[3] Agency for Defense Development, Daejeon, South Korea
{yd.kim,lwjx4f4}@add.re.kr

[4] School of Integrated National Security, Chungnam National University, Daejeon, South Korea
hyeonju.seol@gmail.com

Abstract. Ergonomic design of target symbol is required for fighter pilots to recognize and interpret target infromation effectively since the latest cockpit display provides huge amount of information. The purpose of this study is to analyze the structure of target symbol, establish coding design guidelines, and design ergonomic target symbol based on the results of usability evaluation for fighter pilots. A structure of target symbol and coding design guidelines analyzed in terms of information dimension (e.g., target type, identification friend or foe, acquisition status, maneuvering status, Data source) and coding dimension (e.g., shape, color, line, alphanumeric character) through literature review. Design alternatives for a target symbol were devised by extracting optimal combination of the information and coding dimension. A usability evaluation was conducted by 19 fighter pilots in their 20 s and 30 s using a relative preference rankings on design alternatives for a target symbol. As a result of conjoint analysis based on usability evaluation data, optimal combination of attributes in terms of target type was only shape coding, that in terms of identification friend or foe was shape, color, and alphanumeric character coding, that in terms of acquisition status was shape, color, and line coding, that in terms of maneuvering status was line and alphanumeric character coding, that in terms of data source was color and line coding. This study suggested that an improved target symbol based on the usability evaluation and design method of target symbol which can be applied to a variety of symbol designs such as public signs.

Keywords: Symbol design · Usability evaluation · Conjoint analysis

C. Stephanidis (Ed.): HCII Posters 2018, CCIS 850, pp. 176–182, 2018.
https://doi.org/10.1007/978-3-319-92270-6_24

1 Introduction

A target symbol on cockpit display is a crucial factor for fighter pilots to achieve air operations successfully. Warfighting symbology has been used for delivering standardized information about military objects to a large number of stakeholder groups in joint operations quickly and accurately [1]. Especially, Ergonomic design of target symbol is required for fighter pilots to reduce learning time and prevent human errors in interpretating target infromation since the latest cockpit display provides huge amount of information.

Analysis and evaluation for the effects of symbol coding techniques are needed to design ergonomic target symbol. The objective of the coding techniques is for users to distinguish between individual information, discover functionally related information, realize the relationship between information, and identify important information within a visual display [2]. The coding techniques requires to use cosistent and meaningful coding, guarantee the legibility or transmission time of information, and establish standards for all coding within the system. Meanwhile, optimal combination of symbol information structure and coding techniques can be derived from usability evaluation that reflects acutal users' needs.

The purpose of this study is to establish design criteria and alternatives of the target symbol and propose ergonomic target symbol based on the result of usability evaluation. The design criteria and alternatives of the target symbol were set up by analyzing target information structure and coding techniques through literature review. The usability evaluation was performed by measuring pilots' preference rankings of alternatives of the target symbol. Finally, relatively suitable coding techniques for each target information structure were found by applying conjoint analysis (CA) technique to usability evaluation data.

2 Target Symbol Design

2.1 Design Criteria

Design criteria were defined in the information dimension and the coding dimension through literature review such as military standard, technical order, and journal paper. The information dimension is meaning elements that structure of the target symbol represents, including target type, identification friend or foe, acquisition status, maneuvering status, and data source. Target type refers to the main mission area where the military objects are active and is classified into air, ground, and sea surface. Identification friend or foe means the threat level represented by the military objects and is divided into friendly, neutral, unknown, suspect, and hostile standard identity. Acquisition status defines the condition that an aircraft is tracking the military objects and is classified into air to air next to shoot and air to ground next to shoot status. Maneuvering status is detailed information about motion of the military objects under operation environment and is divided into altitude and airspeed. Data source stands for the main subject that detects the military objects and ownship sensor, offboard sensor, and ownship correlation sensor with offboard.

On the other hand, the coding dimension is expression elements that meaning elements of the target symbol represent, including shape, color, line style, and alphanumeric character coding. Shape coding is classified into circle, triangle, square, diamond, and trapezoid shape. Color coding is divided into red, blue, green, yellow, purple, and white color. Line style coding is associated with solid line, dotted line, double line, vertex line, line direction, and line length. Alphanumeric character coding consists of letters and numbers.

2.2 Design Alternatives

This study examined symbol design guidelines considering human cognitive characteristics in order to create alternatives of the target symbol. For instance, affordance design is necessary for users to understand the symbol meaning and take proper action quickly. Also, two or more multi-dimensional coding design is required to improve human cognitive accuracy.

The alternatives of the target symbol were suggested by prioritizing design for coding dimension in terms of information dimension considering the examined design guidelines. Alternatives for target type were designed with shape coding as the primary means and color, line style, and alphanumeric character coding as the secondary. Alternatives for identification friend or foe were invented by shape and color coding as the primary means and line style and alphanumeric character coding as the secondary. Alternatives for acquisition status were produced by line style and color coding as the primary means and shape and alphanumeric character coding as the secondary. Alternatives for maneuvering status were devised by shape, line style, and alphanumeric character coding as the primary means except color coding. Alternatives for data source were made with shape coding as the primary means and line style and alphanumeric character coding as the secondary except color coding. Table 1 shows an example of the alternatives of the target symbol for identification friend or foe.

Table 1. Alternatives of target symbols for identification of friend or foe

Identification of friend or foe	Alternatives							
	#1	#2	#3	#4	#5	#6	#7	#8
Friend								F
Neutral								N
Unknown								U
Suspect								S
Enemy								H

3 Usability Evaluation

3.1 Method

Usability evaluation data was obtained using questionnaires for each alternatives, and these alternatives were analyzed to identify the best configuration of coding dimensions. To conduct the usability evaluation, a total of 19 fighter pilots at Republic of Korea Air Force in their 20 s to 30 s were asked to take part in the study. The participants determined the relative preference ranking of the designed alternatives of target symbol by coding dimension in terms of information dimension. Then, the best configuration of coding dimension was identified by CA technique.

CA technique is used to predict the users' decision-making through the relative preference of different characteristics and functions of products or service [3]. CA technique defines the different characteristics and functions of products or services as 'attributes' and the several sub-options of each attribute as 'levels' [4]. Researchers can easily identify the reason why users prefer alternatives of target symbols based on pre-defined attributes and the improving direction of alternatives of target symbols based on newly defined attributes which shows potential alternatives for users by using CA technique [5]. In this study, five CA model were established for covering five information dimensions including the attributes and levels of target symbols to conduct CA technique. In CA models, Primary coding dimensions were defined as independent attributes and each coding dimension was divided into specific levels. Meanwhile, secondary coding dimensions were integrated as one attribute (Additional mark) and each coding dimension was defined as each level. Table 2 represents the attributes and levels for target symbols.

Table 2. Attributes and levels for target symbols

Information dimension	Attributes	Levels
Target type	Shape	5 (Shape combination #1 – #5)
	Additional mark	4 (None, color, line style, alphanumeric character)
Identification of friend or foe	Shape	3 (Shape combination #1 – #3)
	Color	3 (Color combination #1 – #3)
	Additional mark	3 (None, line style, alphanumeric character)
Acquisition status	Line style	3 (Solid line, dotted line, vertex line)
	Color	2 (Red, Yellow)
	Additional mark	4 (Shape combination #1 – #3, alphanumeric character)
Maneuvering status	Altitude	3 (Shape, line style, alphanumeric character)
	Airspeed	3 (Shape, line style, alphanumeric character)
Data source	Shape	3 (Shape combination #1 – #3)
	Additional mark	3 (None, line style, alphanumeric character)

3.2 Results

As a result of CA based on usability evaluation data, the different configurations of coding dimension was preferred for each information dimension as shown in Table 3. In this table, weight means the importance of each attributes, while part-worth means the contribution of a level to the total utility and most preferred levels of each attributes are highlighted. Part-worth can be considered as the proxy parameter of relative users' preference score, thus, if a certain level had the highest part-worth, this level was most preferred level for the users.

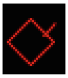
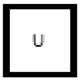
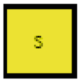
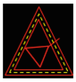
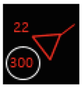
Table 3. Result of conjoint analysis (part-worth and importance weight)

Information Dimension	Attributes	Level (part-worth)					Weight
Target type	Shape	#1 (3.347)	#2 (0.979)	#3 (-1.232)	#4 (-2.442)	#5 (-0.653)	0.574
	Additional mark	None (1.842)	Color (-0.368)	Line style (-1)	Alpha numeric character (-0.474)	-	0.426
Identification of friend or foe	Shape	#1 (0.86)	#2 (0.649)	#3 (-1.509)	-	-	0.382
	Color	#1 (1.018)	#2 (-0.414)	#3 (-0.614)	-	-	0.328
	Additional mark	None (-0.14)	Line style (-0.982)	Alpha numeric character (1.123)	-	-	0.290
Acquisition status	Line style	Solid (0.667)	Dotted (0.298)	Vertex (-0.965)	-	-	0.366
	Color	Red (-0.842)	Yellow (0.842)	-	-	-	0.209
	Additional mark	Shape #1 (0.671)	Shape #2 (1.461)	Shape #3 (-0.013)	Alpha numeric character (-2.118)	-	0.435
Maneuvering status	Altitude	Alpha numeric character (0.596)	Line (-0.614)	Shape (0.018)	-	-	0.608
	Airspeed	Alpha numeric character (0.667)	Line (-0.386)	Shape (-0.281)	-	-	0.392
Data source	Shape	#1 (-0.678)	#2 (2.83)	#3 (-2.152)	-	-	0.625
	Additional mark	None (1.638)	Line style (0)	Alpha numeric character (-1.638)	-	-	0.375

Before identifying the optimal configuration for each information dimension, used code dimensions were analyzed. In Target type dimension, only shape coding was preferred for users. In attributes in terms of Identification friend or foe, Shape, Color and Alphanumeric character coding were most preferable. In attributes in terms of Acquisition status, most preferred target symbol was determined by shape, color and line style coding. In attributes in terms of Maneuvering statue, Alphanumeric character coding was mainly used to identify the altitude and airspeed. Lastly, in attributes in terms of Data source, shape coding was mainly changed depending on data source of other information.

The optimal configurations could be extracted from the utility which was highest in each information dimension. The utility of all possible configurations was calculated by multiplying weight and part-worth of corresponding levels. Table 4 represented the best configurations and actual designed symbols of each information dimension.

Table 4. Best designed target symbols of each information dimension

Information dimension	**Designed Symbols**				
Target type	Air	Ground	Sea		
				-	-
Identification of friend or foe	Friend	Neutral	Unknown	Suspect	Enemy
					
Acquisition status	Air/Air	Air/Ground			
			-	-	-
Maneuvering status	Altitude	Airspeed			
			-	-	-
Data source	Ownship	Offboard	Correlation		
				-	-

4 Conclusion

The present study suggested ergonomically improved design of target symbols on cockpit display based on usability evaluation. In order to design target symbol in systematic and quantitative manner, the information structure and coding techniques of the target symbol were analyzed and the usability evaluation was conducted by pilots on the alternatives of the target symbol. The improved design of target symbols was finally derived from identifying the optimal combination of coding dimension about each information dimension by CA of usability values. The target symbol design method based on usability evaluation in this study can be applied to design various symbols such as public signs.

A usability evaluation with more pilots in the actual flight environment and various ergonomic evaluation measures are needed for further research. This study evaluated the usability through the questionnaires of 19 pilots. However, to verify the utility of improved design of target symbol, a usability evaluation for a larger number of pilots is required to be conducted in the actual flight environment. In addition, this study conducted usability evaluation using relative preference ranking, but using an ergonomic evaluation measures is necessary to analyze users' cognitive characteristics such as recognizability, learnability, memorability.

References

1. MIL-STD-2525C: Common Warfighting Symbology. U.S. Government Printing Office, Washington (2008)
2. MIL-STD-1472G: Human Engineering Design Criteria for Military Systems, Equipment and Facilities. U.S. Government Printing Office, Washington (2011)
3. Green, P.E., Srinivasan, V.: Conjoint analysis in marketing: new developments with implications for research and practice. J. Mark. **54**(4), 3–19 (1990)
4. Silayoi, P., Speece, M.: The importance of packaging attributes: a conjoint analysis approach. Eur. J. Mark. **41**(11/12), 1495–1517 (2007)
5. Yoon, B., Park, Y.: Development of new technology forecasting algorithm: hybrid approach for morphology analysis and conjoint analysis of patent information. IEEE Trans. Eng. Manag. **54**(3), 588–599 (2007)