Interface Design for the Command-control Module Based on Adaptive Interaction Technology

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Abstract. Firstly, the concepts of three adaptive modes are introduced, and the experiment for the interface layout based on the adaptive adjustment interaction is designed, in which the speed of information identification of other 8 regions is sorted under the condition of interference of the intermediate region with fixed constraints. An adaptive interaction experiment of state monitoring parameter interface is designed, and the following conclusions are obtained: Compared with the original chart monitoring interface, the dimensionless and normalized graphical parameter interface can effectively shorten the time to discover abnormal parameters and improve the accuracy rate.

Keywords: Command-control Module; Adaptive Interface; Human-computer Interaction.

1. Introduction

Command and control module is a man-machine interaction site for weapons and equipment combat and training missions [1]. Reasonable command module interface layout is a necessary condition for the effective and accurate completion of the combat mission by the combat personnel [2]. As the only channel for human and weapon systems to transmit information, man-machine interaction interface has become an important practical control system responsible for man-machine interaction, and its display mode directly affects the perception and judgment of combat personnel on the high-density information of the command module, thus directly affecting the combat effectiveness of weapons [3].

The existing missile weapon system generally adopts the traditional static man-machine interaction interface. The characteristic of static human-computer interaction interface is that the display amount, display mode and control mode of interface information are fixed [4]. The interface cannot perceive the operator’s cognitive state and operational requirements, so it cannot provide the most concise and effective information display quantity and the fastest control for the operator in the way of information dynamic change, thus resulting in the low efficiency and reliability of human-computer interaction. Scholars represented by Nielsen generally agree that the next generation of new interfaces should accomplish more personalized and customized tasks [5]. The interface design theory that dynamically adjusts the interface based on user behavior is called the adaptive user interface, which is a design theory that adjusts the elements, layout, structure and attributes of the user interface adaptively according to user behavior, in order to better serve specific user requirements [6]. In order to improve the efficiency and reliability of human-computer interaction interface, a lot of research work has been done. Through dynamic adjustment, the human-computer interaction interface provides the most effective human-computer interaction information and the fastest control mode for operators at the right time and
in the right way [7]. Luzheng Bi et al. [8] combined VAE and PI-TSVM algorithms to propose an adaptive man-car interface based on EEG signals. Experiments show that this interface can effectively reduce the training time of users and improve their driving performance. Sucheta et al. [9] collected user information based on Moodle, classified users according to FSLSM and designed an adaptive network learning APP, which greatly improved the learning ability of users. Yang qiang of Tsinghua university [10] established an attention-guidance model based on content perception, which solved the shortcoming of window stack in the multi-person collaborative emergency management system and enabled the system to display important information in priority. Ge Liezhong’s team [11-13] from Zhejiang Sci-Tech University studied the new line-of-sight assisted bubble adaptive cursor technology, adaptive mouse technology and adaptive mobile phone address book. Ulahannan et al [14] used eye tracking to classify how information usage changes over time in partially automated vehicles. Bender [15] designed an adaptive hardware and software based human computer interface for people with motor disabilities. It can be seen that the adaptive interface technology and theory have been widely applied in some fields, but the research on the adaptive interface of military equipment is little. In this paper, based on the interactive process of the command-control module of a weapon system, an adaptive interface that meets the requirements of the man-machine interaction task of the command-control module is designed in combination with the combat task process.

2. Analysis of Adaptive Mode for Man-machine Interface

The adaptive interface is mainly composed of three parts, which are input, inference and output [16]. In a narrow sense, the adaptive mode can be considered as a form of output, which usually refers to the way that the human-machine interface adapts to the needs of users by changing its own characteristics. As shown in Figure 1, according to the current classification, adaptive methods includes space and time changes. Considering the steps in an interactive operation of the process are in strict accordance with the task flow, the time change does not apply to the man-machine interface. This paper mainly studies adaptive method for a certain type of command-control module’s interface based on space in change, including the changes of interface layout, structure and properties.

3. Experiment on Adjustment Adaptive Interaction of Interface Layout

The dynamic change and adjustment of interface layout is an important way for many human-machine interfaces and interactive systems to make adaptive changes. Combined with the data obtained from eye tracker, identification efficiency for several different regions is analyzed, with the condition that the central region is constrained. Design criteria for the adjustment of direction and location in adaptive interface is proposed.

3.1. Experiment Design

(1) The participants’ information
In this experiment, 20 graduate students of our university, all aged from 22 to 25 years old, are right-handed. No central nervous system disease is found in all subjects during the military examination, no cognitive operation disorder, no naked eye vision or corrected vision above 1.0, no color blindness or color weakness.

(2) Experimental equipment
This experiment uses E-prime software to provide experimental scenes, control the experimental process, and record the objective performance data during the experiment. SMI-RED eye tracker is used to collect eye movement data such as fixation time and fixation point track. The laptop computer with the driver software of SMI-RED eye tracker iView installed is used as the experimental platform. The display resolution is 1920*1080, and the screen refresh rate is 60Hz. The notebook computer of BeGaze 3, the data analysis software of SMI-RED eye tracker, is installed to process the eye movement data measured by eye tracker. MATLAB 2014 is installed for offline analysis of experimental data. Auxiliary experimental equipment includes relevant data connection wire and “dongle” for professional software.

(3) Experimental materials

The experimental materials are shown in Figure 2. The experimental interface is divided into 9 equal-sized display areas, which are: top left, middle top, top right, middle left, middle, middle right, bottom left, bottom middle and bottom right. These areas are numbered 1-9, respectively. Each area has $5 \times 5 = 25$ display cells, which are used to display the information that the experiment needs to present. In this experiment, the English letters “E” and “F” are used as experimental display information to simulate the information displayed in the monitoring interface, in which “E” is the interference information and “F” is the target information. Among the 9 regions, the intermediate region is the information interference region which is subject to fixed constraints, and the other 8 regions are the display region of experimental information.

![Figure 2. Experimental materials for the adaptive interaction experiment of interface layout adjustment.](image)

(4) Experimental tasks

According to the different display areas of experimental changes, the experiments can be divided into 8 groups. The number of each group of experimental display areas is shown in Table 1. The experiment requires the subjects to find the target information “F” in the shortest possible time. Each subject needs to conduct 20 experiments in each group. The position of the target information “F” is randomly generated, with a 50% probability in the middle region and a 50% probability in another region. However, the total number of occurrences in the two regions is the same, both of which are 10 times. During the experiment, the E-prime software records the response time of the subjects’ recognition of the target information, and the eye tracker is responsible for recording the eye movement data during the recognition process.

| Number of Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------|---|---|---|---|---|---|---|---|
| Number of Display Area | 5,1 | 5,2 | 5,3 | 5,4 | 5,6 | 5,7 | 5,8 | 5,9 |

Table 1. Numbers of each group of experimental display area.
3.2. Experimental Process

20 people are assigned to conduct a group of experiments every day, and 20 subjects are subjected to the experiment for 5 consecutive days. The experiment time is from 9:00 am to 12:00 am. The light in the laboratory is kept constant and as quiet as possible, and the equipment used in the experiment remains unchanged. All the subjects have enough rest the day before the experiment, and the following steps are carried out on the premise that the subjects are mentally refreshed and in a good state:

(1) Introduce the overall experimental process and experimental purpose to the subjects, and answer the questions raised by the subjects;

(2) The subjects find a comfortable experimental operating posture, adjust the display angle and seat height, keep their eyes about 0.5m away from the screen, and their eyes fall near the central area of the screen;

(3) The subjects rehearse the experimental procedure. Before the experiment begins, the instructions are presented to the subjects through the monitor. When the subjects are ready, they click the “start” button at the bottom of the prompt message, and the prepared experimental targets appear on the screen. The subjects identify the target information “F” in the experimental interface and click with the mouse after finding it. E-prime software records the completion time, and then the display shows the next target to continue the experiment. Each subject practice the experimental procedure until they can master the experimental operation method. After the rehearsal, make sure that each subject has a full rest before starting the experiment.

(4) Turn on the eye tracker and conduct positioning calibration to ensure the normal enrollment of eye movement data.

(5) Start the experiment according to the experimental sequence.

(6) After the completion of the experiment, the experimental data are exported for collation.

3.3. Analysis of Experimental Results

(1) Response time statistics

The experimental data are summarized and the response time data collected by e-prime software are counted. The average reaction time of each experiment is shown in Figure 3.

![Figure 3](image.png)

**Figure 3.** The average time for each region to react.

As can be seen from Figure 3, under the interference of the intermediate region with fixed constraints, the subjects have different ability to identify regions of different locations without knowing in which region the identified target may appear. The region with the most average reaction time is bottom right (4.09s), and the region with the least average reaction time is top left (3.12s). The order of reaction time is: left top < middle top < left middle < right top < left bottom < right bottom < right middle < right bottom.

The 8 regions are combined according to top, bottom, left and right, and the weighted average statistics of the reaction time are carried out. The weighted average reaction time of the four regions, top, bottom, left and right, is obtained as shown in Figure 4.
Figure 4. The weighted average reaction time.

The statistical data shows that the average reaction time of the left side (3.39s) is less than that of the right side (3.83s) when compared with the right side. The reaction time of the top side (3.33s) is bottom than that of the bottom side (3.85s).

The response time data of the target information “F” in the experimental data are removed when the target information “F” is in the intermediate interference area, and the response time data of the target information “F” in the experimental data are counted when the target information “F” is only in the 8 other display areas. One-way analysis of variance is conducted among different regional locations, and the test level P obtained is shown in Table 2.

Table 2. One-way analysis of variance.

| Position (I) | Position (J) | Standard Deviation | P   | Position (I) | Position (J) | Standard Deviation | P   |
|-------------|-------------|--------------------|-----|-------------|-------------|--------------------|-----|
| 2           | 4           | 4.486              | 0.042| 3           | 4           | 4.882              | 0.066|
| 3           | 3           | 3.819              | 0.011| 6           | 8           | 9.975              | 0.003|
| 4           | 4           | 3.012              | 0.027| 7           | 7           | 5.954              | 0.712|
| 6           | 6           | 12.621             | 0.000| 8           | 8           | 13.926             | 0.001|
| 7           | 7           | 17.382             | 0.007| 9           | 6           | 18.341             | 0.000|
| 8           | 8           | 18.318             | 0.000| 7           | 7           | 4.701              | 0.069|
| 9           | 9           | 20.327             | 0.000| 8           | 8           | 4.149              | 0.037|
| 3           | 3           | 4.149              | 0.037| 4           | 4           | 4.290              | 0.129|
| 4           | 4           | 4.290              | 0.129| 9           | 9           | 16.135             | 0.000|
| 6           | 6           | 7.494              | 0.000| 7           | 7           | 4.313              | 0.031|
| 7           | 7           | 11.359             | 0.004| 6           | 6           | 1.291              | 0.927|
| 8           | 8           | 15.499             | 0.000| 9           | 9           | 7.845              | 0.038|
| 9           | 9           | 19.354             | 0.000| 7           | 8           | 4.575              | 0.043|

Note: when the value in the table is less than 0.01, the difference is significant; when the value is greater than 0.01 and less than 0.05, the difference is relatively significant; when the value is greater than 0.05, the difference is not significant.

It can be seen from Table 2 that, there is no significant difference among the five groups of top right, bottom left, bottom left, bottom right, middle and bottom middle, while the difference among the other groups is at least 0.05, and the difference between the top left and bottom right regions and other regions is significant.
(2) The results of eye movement data

What the Figure 5 shows is the movement trajectory of the fixation point of the subjects in the experiment. The fixation time is the average fixation time of each fixation point. The average fixation time of fixation points in 8 regions is obtained by the BeGaze eye movement data analysis software, as shown in Table 3.

Table 3. The fixation time of each area.

| Area       | Top Left | Middle Top | Top Right | Top Middle Left | Top Middle Right | Bottom Left | Bottom middle | Bottom Right |
|------------|----------|------------|-----------|-----------------|------------------|-------------|---------------|--------------|
| Fixation Time [ms] | 294      | 327        | 353       | 333             | 362              | 347         | 368           | 381          |

In combination with Figure 5 and Table 3, it is found that the average saccade distance of the area on the diagonal is longer than that of the area not on the diagonal. Theoretically, the length of saccade distance will reduce the speed of identifying the target, but not all the areas on the diagonal are slower than those not on the diagonal. For example, the average reaction time of the top left region (diagonal region) is the shortest, even though the jump distance is long. The average reaction time of the top right and bottom left (the diagonal area) is less than that of the top right and bottom left (the off-diagonal area), although it is slower than that of the top right and bottom left (the off-diagonal area). The reason may be that the fixation time has a greater impact on the average response time than the eye-jump distance, and the fixation time in the top left region is significantly shorter than that in other regions, so the target identification speed is the fastest. Similarly, the fixation time in the top right and bottom left regions is longer than that in the middle top and bottom left regions, but shorter than that in the middle and bottom right regions.

(3) Conclusion

According to the results of the average reaction time of each region and the one-factor analysis of variance of each region, under the condition that the interference of the intermediate region is fixed, the order of information speed of the other 8 regions is as follows: top left > middle top > middle left > top right ≈ bottom left > middle right ≈ middle bottom > bottom right. Based on the analysis of eye movement data, it is found that the effect of fixation time on average reaction time is greater than the distance of eye movement.

4. Experiment on the Adaptive Interaction of State Monitoring Parameter Interface

The state parameter is the common display content in the man-machine interface. The designed experiment compares the normal parameter interface with the graphical parameter interface designed after dimensionless and normalized to confirm the accuracy and response time of abnormal parameters, analyzes the advantages and disadvantages of the two interfaces, and provides a design criterion for the state monitoring parameter graphical display when the attribute is adaptive to change.
4.1. Experiment Design
(1) The participants information
It is the same as the experiment on the adaptive interaction of interface layout adjustment.
(2) Experimental equipment
Except that the SMI-RED eye tracker is not needed, the rest is the same as the experiment on the
adaptive interaction of interface layout adjustment.
(3) Experimental materials
The experimental material design of this experiment is shown in Figure 6. Figure 6 (a) shows the original
monitoring interface and designs 6 parameter states that can be used for monitoring, which are displayed
in table form. Figure 6 (b) shows the graphical parameter interface designed after dimensionless and
normalized. The normal interval of monitoring parameters is between the red wireframe and the yellow
interval. The red wireframe is the upper limit of monitoring parameters, and the yellow wireframe is the
lower limit of monitoring parameters.

![Figure 6. Experimental state monitoring parameter interface of adaptive interactive.](image)

(4) Experimental tasks
The experiment requires the subjects to monitor the state parameter information in the monitoring
interface of two kinds of experimental targets before and after the adaptive optimization. Define an
upper bound and a lower bound for the values of the six parameters. Each subject first monitors the 10
original interfaces to find out which parameters are higher than the upper limit or lower than the lower
limit. After a period of rest, the optimized interfaces of the 10 original interfaces are monitored to find
the parameters that are above or below the upper limit. The subjects do not know the display order of the
interface in advance, and the display order of the interface before and after optimization is also different.
The background program records the monitoring completion time and the monitoring accuracy rate.

4.2. Experimental Process
20 people are assigned to conduct the experiment every day, and 20 subjects are tested continuously for
5 days. The experiment time is from 9:00 am to 12:00 am. The light in the laboratory is kept constant and
as quiet as possible, and the equipment used in the experiment remains unchanged. All the subjects have
a full rest the day before the experiment, and the following steps are carried out on the premise that the
subjects are mentally refreshed and in a good state.
(1) Introduce the overall experimental process and experimental purpose to the subjects, and answer the
questions raised by the subjects.
(2) The subjects find a comfortable experimental operating posture, adjust the display angle and seat
height, keep their eyes about 0.5m away from the screen, and their eyes fall near the central area of the
screen.
(3) The subjects rehearse the experimental process. Before the experiment begins, the instructions are
presented to the subjects through the monitor. When the subjects are ready, they click the "start" button
at the bottom of the prompt message, and the prepared experimental targets appear on the screen. After
finding the abnormal parameters, the corresponding number of parameters on the keypad is “1-6”. The
background program records the completion time and accuracy. Then the monitor shows the next target
to continue the experiment. Each subject practices the experimental procedure until they can master the
experimental operation method. After the rehearsal, make sure that each subject has a full rest before starting the experiment.
(4) Start the experiment according to the experimental sequence.
(5) After the completion of the experiment, the experimental data are exported for collation.

4.3. Analysis of Experimental Results
After the completion of the experiment, the number of monitoring errors recorded in the background of the system is exported and sorted out. Table 4 shows the number of errors before and after the adaptive changes of the 10 monitoring interfaces.

| Sequence | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----------|---|---|---|---|---|---|---|---|---|----|
| Original Monitoring Interface | 5 | 4 | 5 | 2 | 1 | 6 | 3 | 4 | 5 | 1 |
| Graphical Parameter Interface | 2 | 1 | 2 | 2 | 1 | 0 | 1 | 1 | 2 | 0 |

As can be seen from Table 4, the error frequency of the graphical parameter interface is less than that of the original monitoring interface, and the overall accuracy rate increases from 92.8% to 97.6%.

The monitoring completion time of 20 subjects on 10 monitoring interfaces is calculated, and the average monitoring completion time is shown in Figure 7.

![Figure 7. Average monitoring completion time.](image)

The pairwise T-test is conducted for the monitoring completion time of the original monitoring interface and the graphical parameter interface. The statistical results are shown in Table 5.

| Group | The Amount of Each Group | The Amount of Each Group | Mean Value | Variance | P-value |
|-------|--------------------------|--------------------------|------------|----------|---------|
| Original Monitoring Interface | 10 | 3.94 | 0.042 | | |
| Graphical Parameter Interface | 10 | 2.40 | 0.032 | | |

6.87 × 10^{-13}
As can be seen from Figure 7, the graphical parameter interface takes less time to complete the monitoring than the original monitoring interface. As can be seen from Table 5, the average monitoring completion time is reduced by 39.1%, and p<0.01, indicating an extremely significant difference. Based on the above data analysis, it can be seen that compared with the original chart monitoring interface, the graphical parameter interface designed after dimensionless and normalization can effectively shorten the time to discover abnormal parameters, and the accuracy rate is improved by 4.8%. Reason analysis: as shown in Fig. 8, for monitoring parameters that exceed the upper limit and fall below the lower limit, when reflected on the graphical parameter interface, the graph will show distortion in a certain direction, which is more intuitive and easy to find than the change of numbers.

![Figure 8. Graphical parameter interface.](image)

5. Summary
(1) The conclusion of the interface layout adjustment mechanism experiment is extended to the adaptive interaction design. When the man-machine interface needs to adjust the layout adaptively, if the intermediate region is restricted and cannot be adjusted, it can be adjusted to other regions according to the importance of the adaptive project to be adjusted. The interface layout can be adjusted according to the left region is better than the right region, and the upper region is better than the lower region. The priority of the specific 8 directions is: top left > middle top > middle left > top right ≈ bottom left > middle right ≈ middle bottom > bottom right.

Taking the adaptive optimization design human-machine interface of command and control system as an example, during the process of adaptive dynamic change, situation display area and other important areas usually fixed in the position of the middle-left, interactive link state parameters of low use frequency area can be adaptive adjustment to bottom right corner of the interface. Adaptive items with moderate degree of importance and interaction frequency can be adjusted to top right and top middle areas.
(2) We can put the results of the experiment on adaptive interface interaction of condition monitoring parameter in the design of the adaptive interaction. For the man-machine interface of traditional digital state parameter, we can use the dynamic adaptive change of graphical parameters interface combined with dimensionless and normalized processing, which can effectively shorten the abnormal parameters available and reduce the failure rate.

Acknowledgement
This research was financially supported by the National Natural Science Foundation of China (51675530)

References
[1] S. J. He, J. Y. Jin, Y. Yang, L. Yan, A review of research on man-machine design evaluation of equipment driving interface, Machine Design and Research. 35(2019): 97-103.
[2] X. Kang, H. N. Gao, R. X. Ding, CATIA analysis on one command-control tank based on virtual man-machine environment, Fire Control and Command Control, 41(2016): 24-27+31.
[3] J. Yang, P. L. Li, W. Wang, Influence of character display of command and control cabin display interface on cognitive load, Comput. Eng. Design. 36(2015): 3306-3310+3323.
[4] V. K. Sucheta, M. P. Radhika and M. M. Manohara, Rule based adaptive user interface for adaptive E-learning system, Education and Information Technologies. 24(2019): (613-641).
[5] J. Nielslen, User interface directions for the Web, Communications of the ACM. 42(1999): 65-66.
[6] V. L. Van, R. Klaassen, User-centered evaluation of adaptive and adaptable systems: a literature review, The knowledge engineering review. 23(2008): 261-281.
[7] A. Kobsa, Generic user modeling systems, User Model. User-Adap. 11(2001): 49-63.
[8] L. Z. Bi, J. W. Zhang, J. L. Lian, EEG-based adaptive driver-vehicle interface using variational autoencoder and PI-TSVM, IEEE T. Neur. Sys. Reh. 27(2019) 18-30.
[9] V. K. Sucheta, M. P. Radhika and M. M. Manohara, Prediction of learner’s profile based on learning styles in adaptive e-learning system, International Journal of Emerging Technologies in Learning (iJET). 12 (2017) 31-51.
[10] Q. Yang, Y. Q. Qin, Y. C. Shi, Content-aware attention guidance interface on interactive tabletops, J. Tsinghua Univ.: Nat. Sci. Ed. 54(2015): 1511-1516.
[11] X. X. Ma, Ergonomic research on gaze-assisted bubble cursor, Zhejiang Sci-Tech University, 2018.
[12] L. Zheng, Ergonomic study on static, adaptive and adaptable in mobile directory, Zhejiang Sci-Tech University, 2011.
[13] H. Liu, Pointing task performance study on adaptive-based mouse, Zhejiang Sci-Tech University, 2014.
[14] A. Ulahannan, P. Jennings, L. Oliveira, S. Birrell, Designing an adaptive interface: using eye tracking to classify how information usage changes over time in partially automated vehicles, IEEE Access. 8(2020): 16865-16875.
[15] M. B. Machado, A. S. Rodrigues, An adaptive hardware and software based human computer interface for people with motor disabilities, IEEE Latin America Transactions. 17(2019): 1401-1409.
[16] Y. Zheng, J. Wang, L. Z. Ge, Review of studies on adaptive user interface, Space Medicine & Medical Engineering. 28(2015): 145-150.