The Rules of Attention Shift on Display and Control Terminal Base on Situation Awareness

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***Abstract*—To investigate the rules of a user's attention allocation and attention shift when they are using a display control terminal, using both methods of information processing, situation awareness theory and eye-movement tracking technology were applied to analyze the influence of different interface element layouts on attention allocation and attention shift. In this study, 26 participants performed an operating task under different display control interfaces, which were divided into two types and used to simulate different situation awareness levels, and the fixation point distribution was recorded as the evaluation index. The participants were asked to perform a daily washing task and a fixed task on the simulation interface of a cylinder washing machine. The experimental results revealed that different situations and different situational awareness levels of the participants influenced the rule of attention allocation and transfer; the information elements on the interface play a key role in the user's cognitive process. The experimental results and users' subjectivities were generally in agreement; thus, the present study could provide ergonomic evidence with display and control terminal interface design.**

***Index Terms*—Situation Awareness; Attention Shift; Eye-Movement Tracking; Cognitive Engineering; Interface Design**

I. INTRODUCTION

A display and control terminal in accordance with a harmonious relationship between a human, a computer and the environment is designed based on the efficient acquisition of visual information and rational attention distribution. Scientifically, human-computer interfaces are developing into complicated and diverse entities; thus, display control interface usability research has reached great importance in the accurate comprehension of visual scanning behavior and the gathering of efficient information about attention distribution. Attention, when processing the information, is usually regarded as an important psychological adjustment mechanism, which can be attributed to the limited information-processing resource and highlight the selective function of perception [1]. There are several studies on the modeling of attention distribution. Senders *et al.* established the first quantitative model of instrument monitoring behavior to analyze visual scanning behavior in the context of the intelligence bandwidth concept [2]. The attention model established by Itti *et al.* combines different visual features such as brightness, color and orientation [3]. Wickens translates the factors affecting attention distribution into information prominence, diligence, expectation and value, and he set up an SEEV model that considers these factors [4]. Nobuyuki *et al.* were the first to establish the attention distributive model of car drivers and to explain the relationship between psychological thinking activity and attention model by using a fuzzy control model [5]. Wu Xu and his colleagues from the Beijing University of Aeronautics and Astronautics started using two main sources of information and finally set up an attention distribution prediction model based on the significance, probability, prominence and diligence of information [6]. However, these models are all based on the dominant character of interface elements, and they predict the attention distribution with the subjective expectation by the users who have certain intentions when using a given interface.

Opposite to these previous results, attention shifts during the task; therefore, it is necessary to realize the dynamic distribution in accordance with different cases. Usage scenarios and using experiences have often been considered to be a major source of user distraction potentially diverting attention away from one functional area to another. Some operational error reviews have even related different situations and different situational awareness levels of the participants influenced attention allocation and transfer even under a same interface. Unfortunately, prior ergonomics investigations have not sufficiently addressed the eye fixation and fixation time distribution related to situation awareness.

In visual activities, attention is highly related to eye movement. In general, eye movement can best show the selective function of attention in visual information processing. The results from several studies prove that attention transformation is highly associated with eye movement during many visual tasks [7, 8, 9, 10]. Moreover, the position of attention transformation and eye movement is the same. By analyzing the general situation of users using the display and control interface of the roller washing machine with classical tasks, this study focuses on analyzing the transformative statement of attention in different functional areas under different tasks. Comparisons are made among the four interfaces to give advice on the arrangement of display and control interface.

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In the present study, we sought to complement prior research by specifically addressing situation awareness that might effects on attention distribution and transition setting by using four high-fidelity roller washing machine simulation interfaces (Fig. 1 shows the interfaces tested in the study). The objective was to compare participants perceptual and performance responses with these four interfaces, which have different designs of five functional areas: power, start, program, button, and screen. The utility of the present study is how the dominant character of interface elements and different situation awareness levels may contribute to participants' attention and transition distraction based on roller washing machine interface and performance degradations.

Based on the literature review [11, 12, 13], it is possible that adjacent elements, and/or prominent elements might lead to greater participant eye fixation time and an increased potential for distraction. Our primary hypothesis was that different designs of functional areas would lead to different eye fixation distribution and operational performance. It was also expected that different situation awareness levels might lead to attention diversion in the same interfaces.

II. Situational-Awareness-Oriented Divisions of User Models

According to the SA model by Endsley [14, 15, 16], to perceive the current situation, to analyze and comprehend the current situation as well as to predict the future situation, we divided our users into three types.

(1) Inexperienced users. These users do not know anything about the washing machine interface. In daily life, they are few in number and are likely to be young people who have recently begun living independently or they could be children. Without any experience and previously developed habits, they use the interface with assistance from the instructions or they use a bottom-up attempt.

(2) Inexperienced users. These users know something about using the control interface of the electric appliances, including new appliances. With some common sense, such users usually try to use the interface from their limited experience, and have a top-down attempt to adapt to the new interface, yet they still have to make a bottom-up attempt again to master certain new functions.

(3) Experienced users. They have a well-organized experience in dealing with interfaces. Normally, they have possessed electric appliances for a long time, or they are senior citizens who are unwilling to change their life style. With outstanding experience, such users will usually try the top-down method.

III. Methodology

A. Apparatus

To study the real situation of interface-using, we made electronic changes in four interfaces of roller washing machines by creating four flash models as the experimental and comparison objects (see Fig. 1).

The experimental interfaces were put on the Stimulus display end, with a resolution ratio of 1440×900, an average brightness of 120cd/m^2, and an average illumination of 600lx. The SMI-RED from Germany was adopted to record the eye movement because it can trace the eye movement by an IR camera on the bottom, and the subjects can freely move their heads to some extent without any equipment. The SMI-RED also maintains accurate measurements.

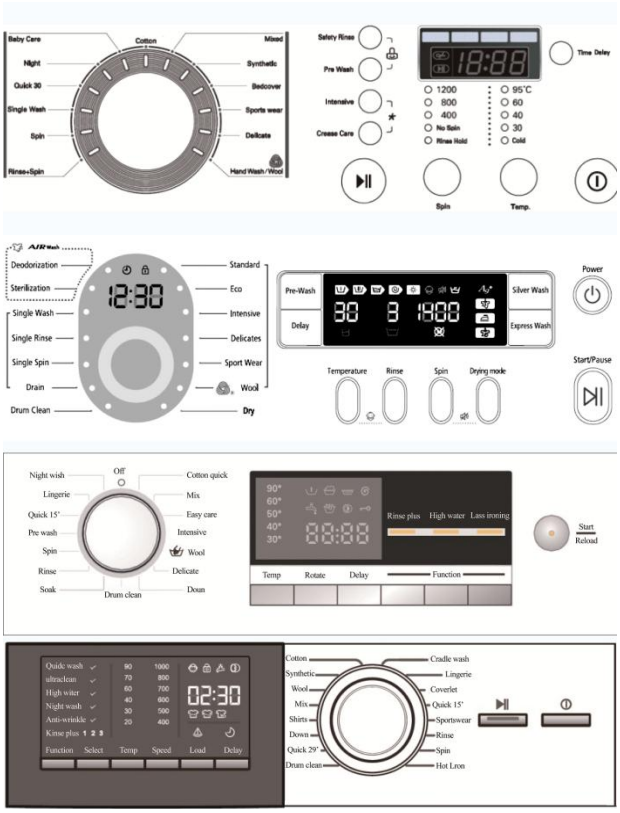

Figure 1. Flash model of four machine interfaces

B. Participants

This experiment entailed interviewing 26 people, 20 of whom were 26- to 40-year-old females who frequently use the roller washing machine, have and use the roller washing machine at home, were right-handed, had visual acuity (including corrected visual acuity) over 1.0, and did not have color feebleness or color blindness. They are divided into 2 groups. Group A consisted of the inexperienced users who executed tasks without getting accustomed to the testing interfaces, while group B, the experienced people, were familiarized with the interfaces in advance.

C. Experiment Design

According to the general habits of the users, the testing interfaces were arranged differently and contained the following five elements: power buttons, start/pause, rotary knob, display screen and functional button as elements 1 to 5. The experiment maintains two parts: task and free use. The users got acquainted with the procedure of attention transformation features of different interfaces, and they talked about their overall feelings. Eye movement was traced in the whole experiment.

D. Experiment Procedure

(1) Warming up: introduce the method of using flash and tips of using eye tracker to the users and lead them to be seated at the chair 50 cm away from the display screen and adapt themselves into comfortable gestures. Calibration should be made on heads and eyes. Before each testing, the eye trackers should be controlled by nine matrices. The users were required to keep their head and body as stable as possible.

(2) Practice: before testing, the users will practice once on the testing interface.

(3) Testing: four interfaces will be tested individually, and for each test, control measurements should be conducted to ensure the accuracy of eye trackers.

(4) Two Tasks: there are continuous single and open tasks for each interface. Group A conducts a single task first and then open tasks, while group B is the opposite of group A. After each task, the users will be asked to mark on the interface, ranging from 1 to 5 points. The appearance of interfaces are random, so different users will finish the interfaces in a different order.

IV. Result and Discussion

To know the attention distribution and scanning features of the users, we made a contrast between the inexperienced and experienced users to conclude how the elements affect attention. We also divided the five elements of the interface into 5 areas of interest (AOI, see Fig. 2). We analyzed the rational features of interface arrangement in terms of attention time, percentage of focus as well as matrixes of focus in every AOI.

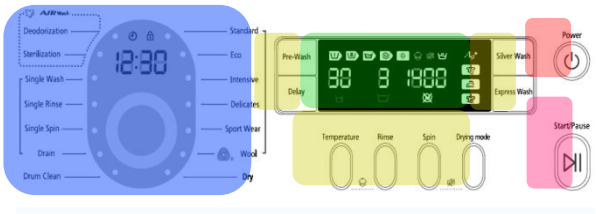

Figure 2. Divide the interface into 5 AOI (interface 2)

A. How the Position, Size and Shape of Power Buttons Affect Attention

The task of turning on the washing machine is very easy. The inexperienced users and experienced users took a similar amount of time to complete this task except interface 3. We observed how the users make decisions by their scanning trace.

Interface 1: when attempting to locate the power button, users tended to look at the top right corner, and they finally found that it is in the bottom right corner. The overall tendency can be described in the picture below. All of the users finished this task swiftly and easily.

Interface 2: The inexperienced users first look at the top right corner and are attracted by the start button, thus making an attention transformation. They find it is not the target and return soon (see Fig. 4). They are affected by the start button, but they can still position it as quickly as the experienced users.

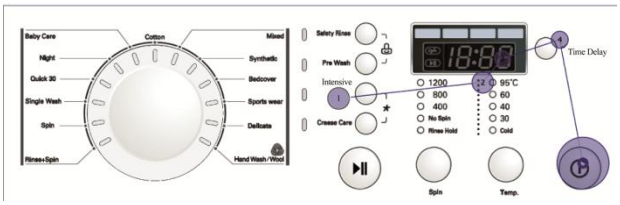

Figure 3. Saccades path of A05 by completing power task (interface1)

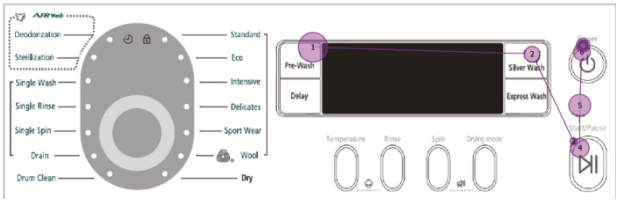

Figure 4. Saccades path of A01 by completing the power task (interface2)

Interface 3: all of the inexperienced users have the same problem in this section: they are attracted by the start button with focus on the right side which is not right at all. They even touch the start button until the failure shows that they are wrong. Some of them cannot complete the task until the host gives them some information (see Fig. 5). Some experienced users make some mistakes too, but all of them can eventually complete the task (see Fig. 6). Inexperienced users complete this task slowly with great difficulty, some even failed to do it, while the experienced users performed much better.

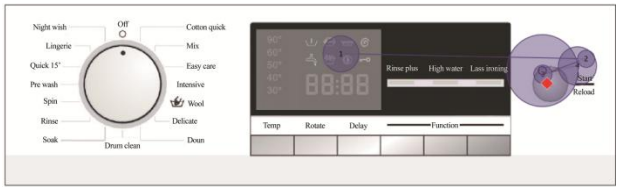

Figure 5. Saccades path of A05 by completing the power task (interface3)

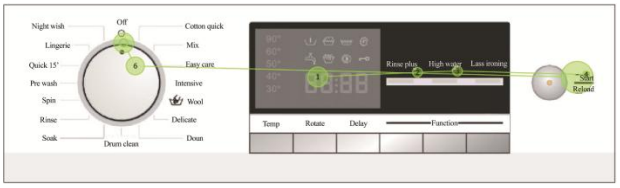

Figure 6. Saccades path of B04 by completing the power tasks (interface3)

Interface 4: all of the users scan to the right side. Because the power button and start button have similar sizes, shape and color, with pictures but no words, the inexperienced users spend a lot of time considering the pictures (see Fig. 7), while the experienced users will quickly recognize the power button. The users need attention distribution to click correctly (see Fig. 8). Therefore, they cannot finish the task swiftly, especially when they have difficulties in positioning. The inexperienced and the experienced users do not differ in time, but rather in efficiency.

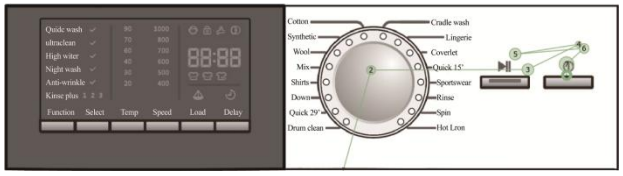

Figure 7. Saccades path of A04 by completing the power task (interface4)

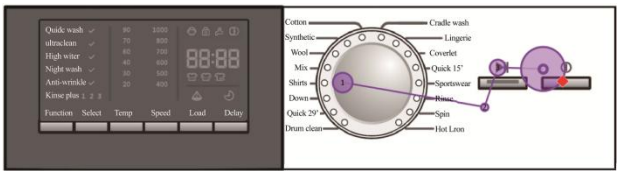

Figure 8. Saccades path of B01 by completing the power task (interface4)

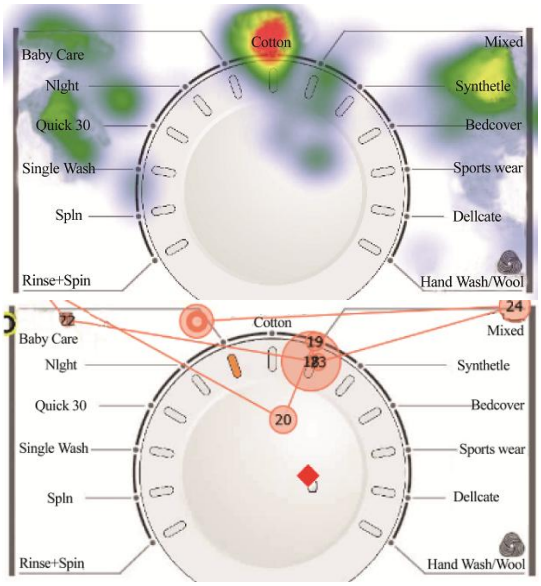

Figure 9. Heat map and Saccades path of the program knob (interface1)

It is well known that most human beings are right-handers. Generally speaking, inexperienced users will resort to their experience to have a top-down attempt, and they are likely to look the right side when they come across a new interface, easily being attracted by shape, size and color, when their experience cannot help (see interface 3). The attention distribution becomes urgent; they need to try bottom-up to become familiar with all of the elements, and when the arrangement of the interface is too creative, the users may be confused and cannot finish the task independently. The attention transformation of the experienced users is clear, with correct positioning, but when the shape of the button is dramatically changed (see interface 4), they may need more time to think.

B. How the Program Knob Distribution of the Washing Machine Affects Attention

Research shows that users care about the washing procedure as well as the different preset parameters; therefore, the users should choose their optimal procedure and their attention will remain in the area for a long time. A well-organized arrangement can accelerate the process of selecting information. A heat map is used to analyze important information, and the warm color is used to mark dynamic changes in time and position.

Interface 1: (see Fig. 9) Users attach importance to the central part of the rotary knob because of their interest in it. The users are accustomed to look from the left to the right to find their desired procedure. Attention is focused more in the upper region, and the inexperienced users can position and swiftly.

Interface 2: Dotted box and brackets are used to divide this section, which makes it is very convenient for the users to find. Attention is focused on the procedure that they use most frequently. First, they will try an up and down method of scanning and they will stop at each part to judge whether it is their target. The inexperienced users can position easily and swiftly.

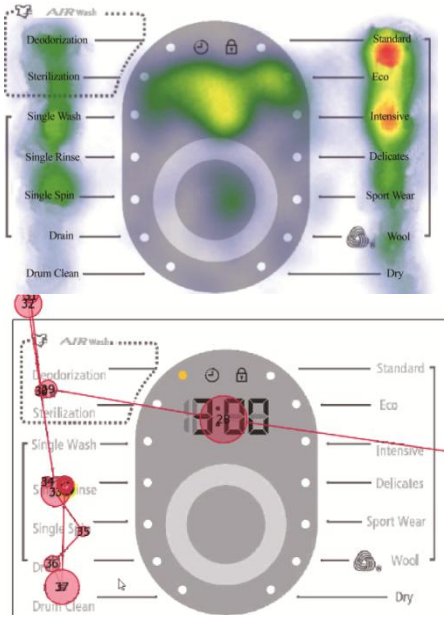

Figure 10. Heat map and Saccades path of the program knob (interface2)

Interface 3: The power function is combined with the rotary knob, and the power-control part is above, which is an area that the users are likely to look at. In the upper left-hand corner, the rotary knob is always noticed first by the users, but they seldom use it. The procedures that are often used are arranged to the right side. The users worry that when they control it from the left to the right side, they might touch the power button, so they tend to be more careful, which consequently affects the attention distribution transformation. The inexperienced users have difficulties in positioning, which makes them inefficient at completing this task.

Interface 4: in this interface, the types of procedures are optional. Different types of procedures are not arranged in a well-organized manner around the knob. The users need to read the instructions to find the procedures that they need. For example, there are two fast-washing procedures but they are arranged awkwardly such that the users cannot use it efficiently. It is very

difficult for users, especially the inexperienced users, to use this interface.

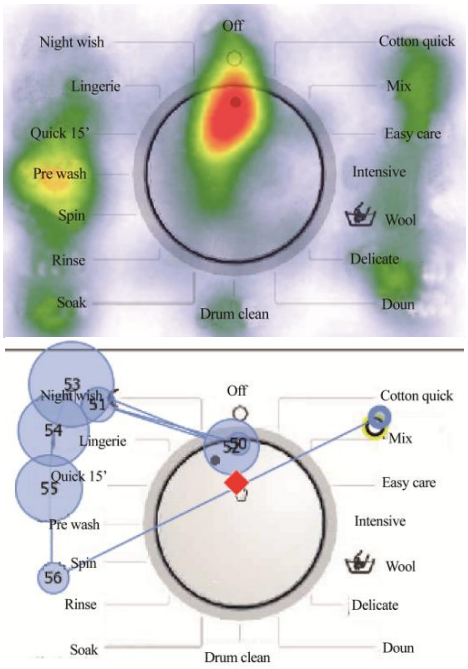

Figure 11. Heat map and Saccades path of the program knob (interface3)

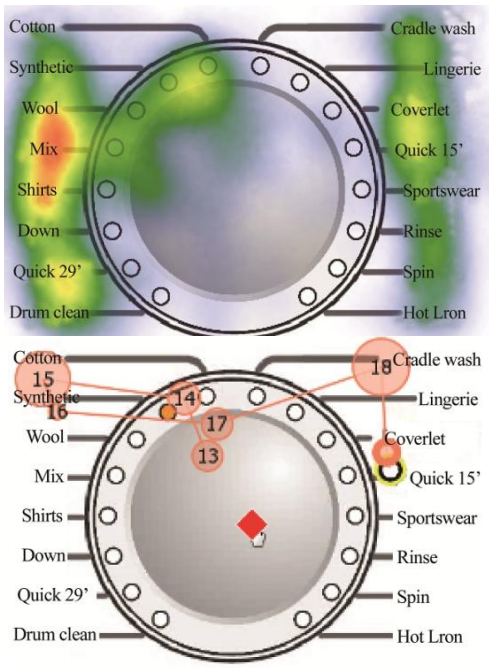

Figure 12. Heat map and Saccades path of the program knob (interface4)

In summary, the inexperienced users are accustomed to seek information in a left-to-right manner, judging from the overall classification and positioning of their targets, and then they find the targets in an up-down manner. Based on this analysis, the users' attention is mostly focused on the upper region. Therefore, it is useful to determine the procedures the users like to use, and arrange those in the upper areas.

C. How the Arrangement of Functional Buttons Affects Attention

The functional buttons are all arranged in a unique manner among the four interfaces to study how different arrangements affect attention. In this section, the eye movement between inexperienced users and experienced users is quite different, which suggests that the arrangement does affect the users greatly.

Interface 1: in this section, the users are required to start two functions of crease care followed by a 3-hour delay (see Fig. 13). When starting the former task, the inexperienced and the experienced users are similar; however, while starting the latter task, users have much more eye movement, especially the inexperienced users who require two times as much eye movement as the experienced users.

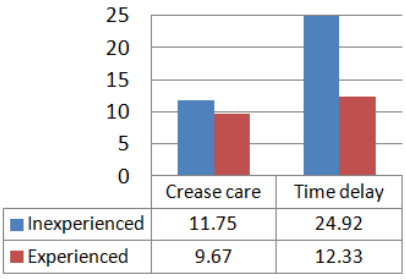

Figure 13. The average saccadic number cost to complete open special functions task by novice and experienced users

In this interface, with the crease care functional button being near the knob, users can easily position it. However, the time delay button is too far away from other buttons, which is easily ignored by users. Moreover, there is another button that is very similar to this one, which may mislead the users. According to the habit of the users (top-down), all of the functional buttons should be located in close proximity to each other. If one functional button is too far away from its group, the users may have difficulty finding it, they might find it with lower efficiency, or they might even fail to find it unless the host assists them. Fig. 14 and Fig. 15 are the scanning traces of inexperienced users.

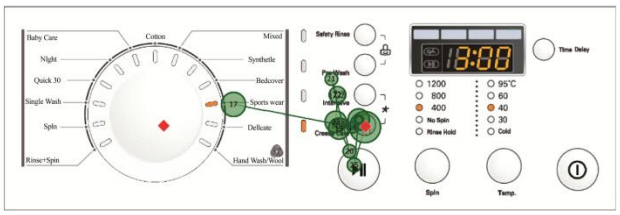

Figure 14. Saccades path of A03 by completing the open crease care task

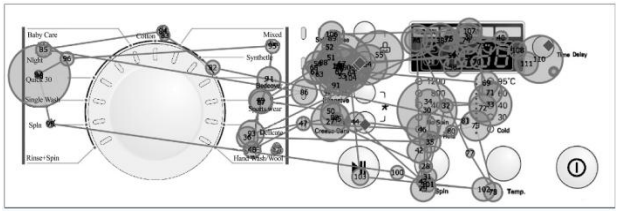

Figure 15. Saccades path of A03 by completing the time delay task

Interface 2: in this interface, the users are required to start the functional button of "silver wash." When they try it, they read the functional buttons on the left first, and then read the parameter button below the screen, and then look from left to right. After a series of eye movement, they finally complete the task. In this interface, the four functional buttons are arranged on the two sides of the screen, and the first side near the knob can be easily noticed by the users, while the other is much more difficult to be noticed. The scanning trace of inexperienced users is described in Fig. 16.

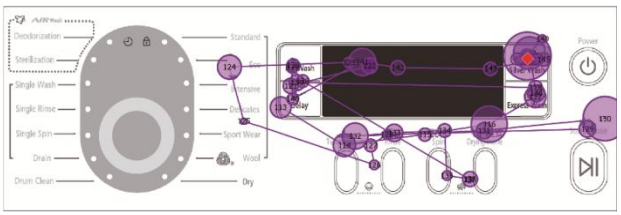

Figure 16. Saccades path of A02 by completing the open silver wash task

Interface 3: in this interface, the users are required to set the rotation speed to 1200, and they also need to start the functional button of the high water level. Most of the inexperienced users mistake the written instructions above the button for the button. Through the eye movement, we observe that they do not notice the button, but they just click the words instruction directly. In our interview, they reply that they just regarded the words as the button, and the button as a dent in the screen.

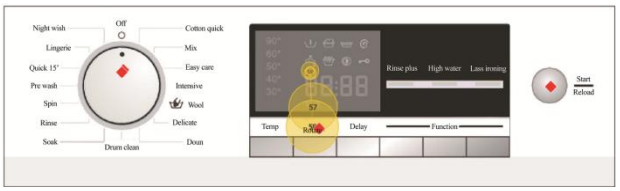

Figure 17. Saccades path of A11 by completing the adjust speed task

The high water level functional button is separated from the area of the functional buttons with vague written instructions so inexperienced users cannot comprehend their relationship clearly, and they mistook the words as the buttons, which in their eyes is not user-friendly. In such way, users cannot use it efficiently.

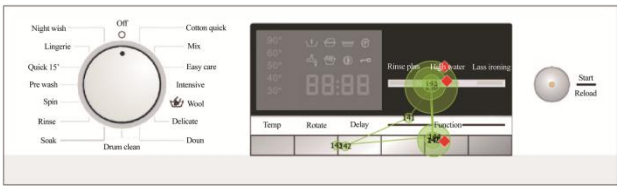

Figure 18. Saccades path of A12 by completing the high water level task

Interface 4: in this interface, all of the functional buttons are in the functional menu. The users can freely choose it by clicking different functional buttons, and they can click the optional button to start. Although all of the users can use it correctly, most of them do not like it. They prefer a design of separated functional buttons. In interface 4, the users need to click the menu button several times, and their eye movement correlates with the cursor, which costs a lot of time and results in lower the efficiency. Experienced users do not think highly of this arrangement; they prefer separated buttons which are easier to locate.

The functional button design of four interfaces shows that the inexperienced users are likely to search for the target among adjacent elements; thus, the buttons with similar function can be located together near the knob or the screen. The buttons and their written instructions should be well-organized which can enable the users to locate them efficiently. Each functional button should have its independent button as much as possible, so that the users will not need to read the instruction for help. When the users are accustomed to a certain functional button, they may find it directly and swiftly. This is especially true for the experienced users.

D. The Rules of Attention Transition Among AOI

By tracing the eye movement in the four interfaces, we calculated the probability of attention transition from one area to another, which enabled us to determine the general rules of attention transition among different AOI.

From Fig. 19 and 20, the transition of attention in interface 1 and 2 is not logically well-organized. The users can be easily attracted by fresh elements or adjacent elements. Their eye movement does not follow a general pattern, and their efficiency of use is poor.

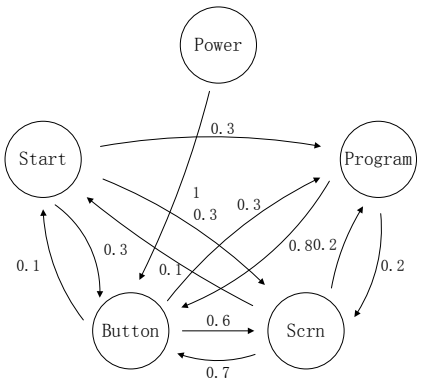

Figure 19. Transition probability of the user's attention among AOIs (interface1)

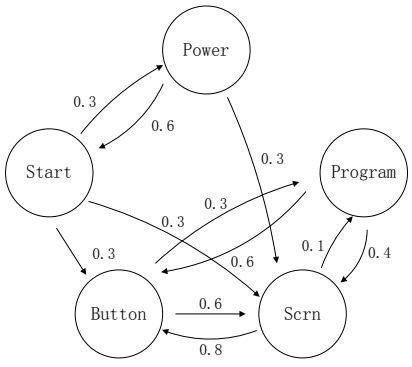

Figure 20. Transition probability of the user's attention among AOIs(interface2)

As shown in Fig. 21 and 22, the users of interface 3 and 4 can basically form a transition process in the following order: power button, washing procedure, display screen, functional buttons and start button. This process is in accordance with the usage habits.

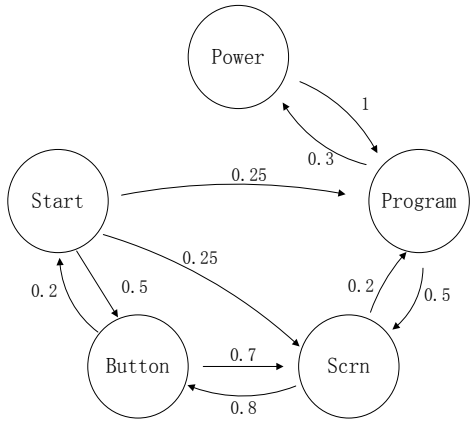

Figure 21. Transition probability of the user's attention among AOIs (interface3)

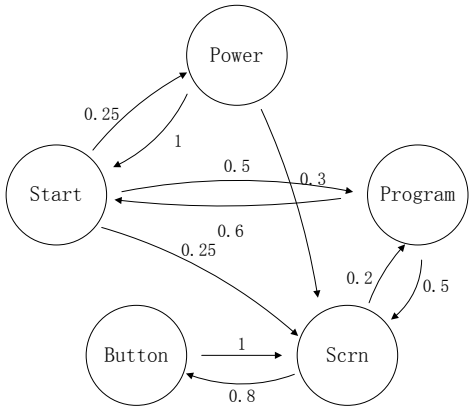

Figure 22. Transition probability of the user's attention among AOIs (interface4)

V. CONCLUSIONS

(1) Different situations have different effects on attention distribution and transition. The inexperienced users need to process the element information, which is in top-to-bottom order [17]. According to this research, we have knowledge of how the interface elements affect attention in different situations.

(2) Under the circumstance of different levels of consciousness, people can perceive the significance and probability of the information to some extent. By processing the information features, the attention can shape a working memory, which is from top to bottom and in accordance with the feature-integration theory of attention [18]. The eye movement data provided by this study is in accordance with the users' subjectivity, which strengthens our conclusion.

A visual display terminal should be in accordance with a harmonious relationship between humans, computers and the environment. Its design should be based on the efficient acquisition of visual information and rational attention distribution. Only by combining these two effects scientifically can we design products with a harmonious relationship between humans, computers and the environment.

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