Misperception Model-Based Analytic Method of Visual Interface Design Factors

Xiaoli Wu[1,2], Chengqi Xue[2], and Zhou Feng[1,2]

[1] College of Mechanical and Electrical Engineering, Hohai University, Changzhou 213022, China
wuxlhhu@163.com, yutakazf@gmail.com
[2] School of Mechanical Engineering, Southeast University, Nanjing 211189, China
ipd_xcq@seu.edu.cn

Abstract. The unreasonable design of interface information has given rise to malfunctions of cognition and decision-making among operators, thus leading users into a complex cognition and finally resulting in serious failures in information recognition and analysis, and even in operation and execution processes, which poses one of the major causes for many accidents. Firstly, there remains an internal relevance between errors and perception, and five error factors i.e., visual confined, visual interference, visual illusion, attention shift and over attention were extracted from the point of visual attention mechanism; Secondly, the cognitive model (theory) and psychological experimental paradigm corresponding to the cognitive level were combed out through explanation of the error level, thus the misperception model was established; Finally, It provides a feasible basis for design improvement of visual interface through behavior and physiological experimental data. This misperception analysis method of visual interface has applied mature psychological experimental paradigm and can favorably analyze the design factors from the aspect of misperception, so as to play a significant role in improving the visual interface design.

Keywords: Visual interface, Visual attention mechanism, Misperception model, Design factors, Error factors, Psychology experiment.

1 Introduction

With the rapid development of industrial design and computer interactive media, visual information interface has become an essential information interactive medium in a complex system. The unreasonable design of interface information has given rise to malfunctions of cognition and decision-making among operators, thus leading users into a complex cognition and finally resulting in serious failures in information recognition and analysis, and even in operation and execution processes, which poses one of the major causes for many accidents. Errors are common human failures occurring in information interface and its cognition mechanism of errors is an important hitting-point for improving interface design as well as the key for reducing

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cognition difficulties. In this paper, by extracting the error factors from the visual attention mechanism, the misperception model build a method to analyze the visual interface design factors, which provides a feasible basis for design improvement of visual interface through behavior and physiological experimental data.

2 Misperception Model

2.1 Extraction of Error Factors in Visual Attention Mechanism

The ability to quickly find what objects are interesting and meaningful out of large amounts of visual data is called visual selective attention[l-4]. This is an essential feature of visual information processing formed during the long and complicated evolution and development of biological visual system and its interaction with nature[5-6]. There are two types of visual attention processes: the first one is pre-attentive process which focuses on attract attention, the second one focused attentive process which is a process of pay attention[7]. What guides visual attention can be bottom-up data driving factors or top-down task driving factors. Accordingly, the selective attention of visual information can be realized through two patterns. First, the reason why an individual chooses a stimulus in the visual attentive field is that the individual considers the stimulus very important in reaching the current task objective. Therefore, under this condition, the task objective and subjective intention of the individual command the visual attentive process. Cognitive psychologists call this kind of active selective attention mechanism goal-directed attention or top-down selective attention; second, because of the fact that a stimulus within the visual field has extraordinary features different from other surrounding objects, the individual's attention is automactically captured by this conspicuous stimulus, in spite of the current task objective or subjective intention of the individual. This type of passive selective attention mechanism is called stimulus-driven attention or bottom-up selective attention, as shown in Fig.1.

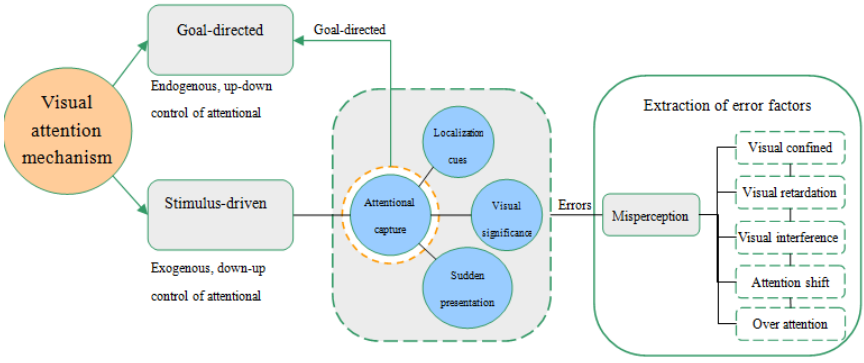

Fig. 1. Extraction of error factors in visual attention mechanism

From the error types research perspective, Norman [8] (1981) proposed to classify errors as three types, i.e., error, fault and failure. Reason [9-10] (1987) put forward eight basic error types including misperception and attention failure on the basis of the theory of Norman; Li Leshan [11] (2004) considers negligence and over attention as two primary aspects leading to users' errors. Supported by previous study results, i.e., error types of misperception proposed by Norman and Reason, this paper has further established the connection of errors and perception through visual attention mechanism. Misperception factors are extracted as visual confined, visual illusion, visual interference, attention shift and over attention respectively, as shown in Fig.1

2.2 Establishment of Misperception Model

This model is divided into error level and cognitive level; error level includes five types, i.e., visual confined, visual illusion, visual interference, attention shift and over attention. Through error explanation, the error level will shift to relevant cognitive model (theory) and psychological experimental paradigm corresponding to the cognitive level, as shown in Fig.2.

1. Visual confined: blind, visually impaired, or out of sight
2. Visual retardation: Reaction was too late, no stimulation or stimulation is not obvious
3. Visual interference: the target transfer, distracted because of the stimulus is not obvious
4. Attention shift: visually impaired, unable to cope with multiple targets
5. Over attention: overly concerned and do not know or misjudgment

That can be entering cognitive level. Through explanations of error level, we have obtained the corresponds of cognitive level with relative cognitive processing theories. Those are visual confined to visual search, visual retardation to perceptual organization, visual illusion to cognitive laziness & cognitive busyness, visual disturbance to attentional capture, attention shift to top-down attentional set, and over attention to focusing attention & sustained attention. We can establish cognitive stratified model of misperception, as shown in Figure 2. They will be explained from cognitive theories.

There are several relative theories in cognitive stratified model of misperception, such as preview search, perceptual load theory, prioritizing selection mechanism, schema model, cognitive load theory, perceptual selected model, susceptibility to interference model, energy distribution, biased-competition model, attentional load theory, and so on. Conceptually-matching theory, that can be called top-down processing, states subjective factors for the guiding role of the perceptual process. The factors are knowledge experience, motivation and expectation. The interpretation mechanism of prioritizing selection in preview search in detail and comprehensively verified the visual-marking-based interpretation in the two aspects: the location-based inhibition and feature-based inhibition of old distractors（Hao F., 2006）[12]. Visual prioritizing selection indicated that the visual system would give priority to the

selection of current behavioural and target-related stimulus and ignore irrelevant stimulus (Han Sh. H, 2000) [13]. Cognitive busyness or cognitive laziness and believed that the lack of motivation caused cognitive laziness and that high processing load caused cognitive busyness (Pett and Wogeber, 2001) [14]. Neisser proposed Attention model-schema model and believed that the attention was not a filter or attenuator. The event importance was not responsible for memory entering decision. And the objects of the individual attention were closely related to the task-activated schema (Neisser, 1976) [15]. Lavie proposed attention load theory and believed that attention selection depended on the amount of current processing resources, which had limited capacity (Lavie et al., 2004, 2005) [16-17]. The biased-competition model based on object attention, in which Desimone proposed that many objects in visual search scene competed attention resources for attention resources were limited. If the characterization of certain object is the same to the target template kept in the current working memory, the object will gain a competitive advantage in prioritizing selection for visual attention (Desimone et al., 1995) [18]. The susceptibility to interference model, in which Dempster proposed that the inhibition processing regulated the resistance to interference and that interference resistance efficiency

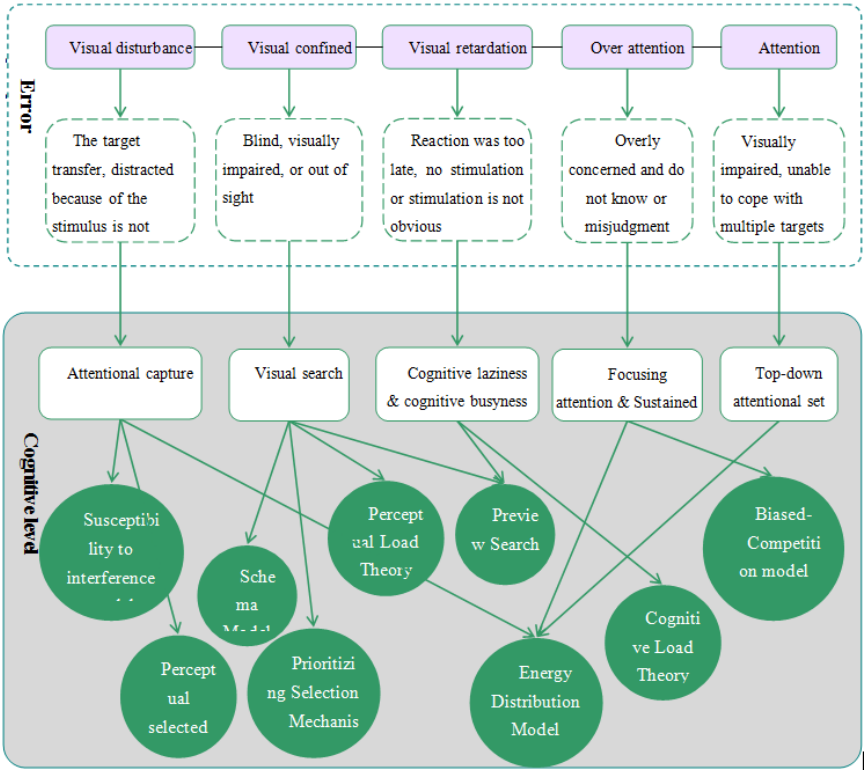

Fig. 2. Misperception Model

reflected the individual susceptibility to interference, the operation-consumed susceptibility under a variety of interference stimulus conditions (Dempster et al., 2003) [19]. These cognitive processing theories above provide base for the study on qualitative analysis experiments of misperception model.

3 Method

Based on the misperception model, a psychological experimental method has been built for analyzing visual interface design factors, which could be conducted as per the following three steps: firstly, extract the error factors of visual interface design factors to be analyzed; then, select relevant cognitive model (theory) and psychological experimental paradigm and apply the error factors as independent variables to design the experiment; lastly, employ the method combining reaction time and eye movement tracing to carry out the experiment. The analysis of variance method is adopted to statistically analyze the indexes of reaction time, and error rate as well as the indexes of saccade frequency and saccade amplitude in physiological data, thus obtaining the misperception analysis result of visual interface information factors, as shown in Fig.3.

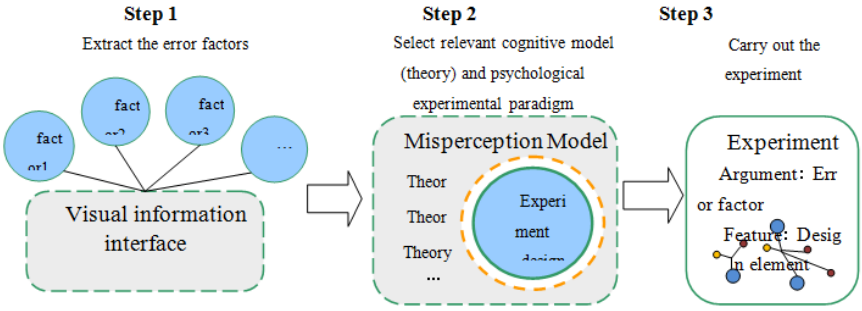

Fig. 3. Analytic method of design factors in visual interface

4 Example

4.1 Extract the Error Factors

In this paper, as an example of visual interface in complex system, the error factors of interface task are extracted. There are 15 tasks information in this radar situation-interface, and it can be listed 17 probable error factors from information display corresponding four monitoring tasks, which are surveillance/discover, status query, response plans and response execution. The text step is error characterization according to misperception model, which are visual confined, visual interference, visual retardation, attention shift and over attention. It can be selected error factors of

visual interference as the independent variables in order to carrying out our experiment with corresponding experimental paradigm.

4.2 Select Relevant Cognitive Model (Theory) and Psychological Experimental Paradigm

There are several relative theories and model for attentional capture in cognitive stratified model of visual interference, such as perceptual selected model, susceptibility to interference model, biased-competition model, attentional load theory, and so on. As for the experimental paradigm study on visual search, Theeuwes[20-21] et al. (1998, 2004) have held the opinion that, the occurrence of attention capture mainly depends on the significance level of the feature of one stimulus relative to that of other stimuli. The higher the feature significance level of a stimulus, the higher the possibility of its generating attention capture. Fleetwood and Byrne[22-23] (2002, 2006) have found through experimental observation that, the first factor which influence the user's visual search is the quantity of icons, the second is the target boundary, and the last one is the quality and resolution of icons. Patrick[24] (2003) has applied the experimental paradigm of visual delay search task to comparatively study the binding experiment of colors, positions as well as colors and positions, the results showed that the binding experiment had not obviously shortened the search time compared with the other two groups of experiments. Yu Bolin[25] et al. have studied the role of word gap played in visual interference, adopted the same-different matching task and visual search with the time series presented by word gap and stimulus as the variables. These two experiments validated that, word gap is a necessary and sufficient condition for visual interference derived from context. Van Orden[26] et al (1993) have employed the brightness and flash as the ways of highlighting to study the shapes and colors of symbols, and testified to the influence of symbol shapes and colors on search time. Wickens[27] et al. (1990) have studied the information identifications in different color codes and spacial positions under multiple information channels. According to the above experimental study review of visual search, information symbols such as color, shape, typeface, position as well as icon quantity and quality have possessed a large experimental study basis, and their interactive interference effects have been primarily demonstrated by experiments. Although these are all basic psychology experiments, they have certain reference value for practically applied of radar situation-interface, based on which, the preliminary presupposition of this experiment could be obtained.

4.3 Experiment

This paper is to conduct an experimental study on fighter situation-interface feature search: simulate the radar situation-interface of complex system, extract the associated factors of visual interference, apply the technological means of psychological experiment on such aspects like interference environment and features of information matter, carry out the visual interference experiment of target search, analyze the attentional capture and search strategy of identification of different

information matters in different interference environments according to the features of visual selective attention and explore the law of the influence of interference environment and information matter features on visual search.

4.4 Result

Based on previous studies, the information matter in the radar situation environment was designed into three kinds of different feature items as per the shape and color type features. Data indicated that (Fig.5, Fig.6), under low-interference and high-interference environments, with the progressive increase of quantity, feature items showed an obvious trend of progressive increase in reaction (Fig.5), and feature 3 (irregular shape-hybrid colored feature item) consumed the longest time; more reaction time was needed in high-interference environment than in low-interference environment. Data also indicated that (Fig.7, Fig.8), the error rate presented a law different from that in reaction; in low-interference environment, feature items 1, 2 and 3 showed a trend of progressive increase, which suggests that regular-shaped single colors are easier to search than irregular-shaped single colors and hybrid colors, and not susceptible to causing misjudgment issues; in high-interference environment, the error rate showed no obvious trend of progressive increase, which also suggests that, in an environment with multiple interfering objects.

Under both low-interference and high-interference environments, the reaction time and error rates of the subjects were tested when the three different feature items were presented by different quantities. Variance analysis on the reaction time indicated that, the main effect of feature items under low-interference environment ($F=24.781$, $P=0.001$, $p<0.05$) and the main effect of feature items under high-interference environment ($F=10.184$, $P=0.012$, $p<0.05$) both had reached the significance level (as indicated by Fig.4); variance analysis on the error rate indicated that, the main effect of feature items under low-interference environment ($F=5.297$, $P=0.047$, $p<0.05$) had reached the significance level, while the main effect of feature items under high-interference environment ($F=1.613$, $P=0.275$) was insignificant (as indicated by Fig.5).

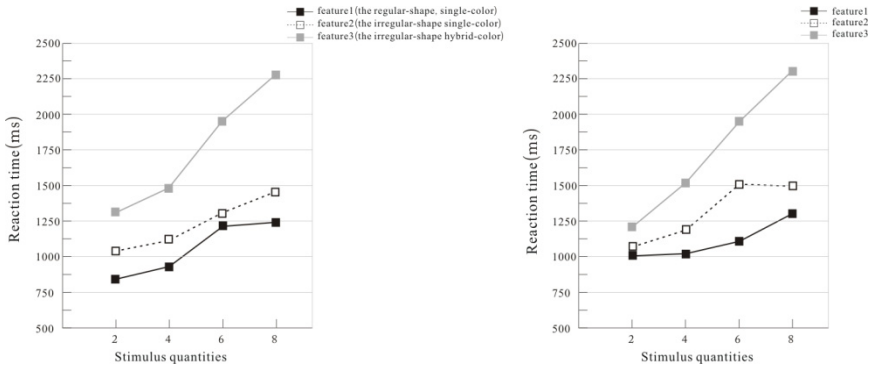

Fig. 4. Reaction time of the three feature items under low-interference and high–interference environment

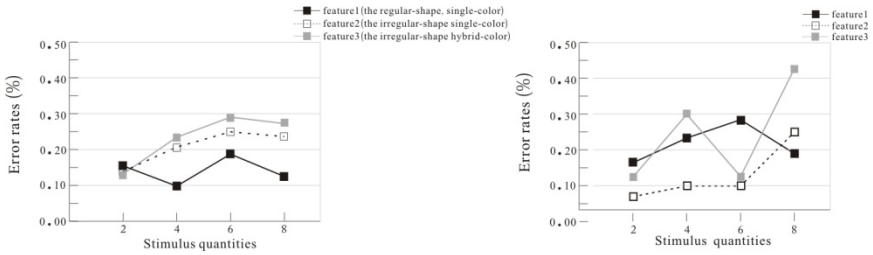

Fig. 5. Error rates of the three feature items under low-interference and high–interference environment

5 Conclusion

1. There remains an internal relevance between errors and perception, and five error factors i.e., visual confined, visual interference, visual illusion, attention shift and over attention were extracted from the point of visual attention mechanism;
2. The cognitive model (theory) and psychological experimental paradigm corresponding to the cognitive level were combed out through explanation of the error level, thus the misperception model was established;
3. Error factors were applied as independent variables to change previous psychological experimental method and were able to analyze the key factors of visual interface design on the aspect of misperception.
4. Interference environment and information matter features both have played important roles in influencing the information identification in radar situation-interface, which is the design factor needing to be considered in the information layout of complex situation-interface.

This misperception analysis method of visual interface has applied mature psychological experimental paradigm and can favorably analyze the design factors from the aspect of misperception, so as to play a significant role in improving the visual interface design.

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References

1. Shen, J.: Guidance of eye movements during conjunctive visual search: The distractor-ratio effect. Dissertation Abstracts International: Section B: The Sciences and Engineering 63(2B), 6126 (2003)
2. Schweizer, K.: Visual search, reaction time, and cognitive a-bility. Perceptual and Motor Skills 86(1), 79–84 (1998)

3. Williams, C.C.: Age differences in visual memory and the re-lation to eye movements and executive control processes in visual search. Dissertation Abstracts International: Section B: The Sciences and Engineering 64(8B), 4080 (2004)
4. Underwood, G., Chapman, P., Brocklehurst, N., UnderwoodJ, C.D.: Visual attention while driving: Sequences of eye fixations made by experienced and novice drivers. Ergonomics 46(6), 629–646 (2003)
5. Lee, T.S.: Computations in the early visual cortex. Journal of Physiology 97, 121–139 (2003)
6. Grill-Spector, K., Malach, R.: The human visual cortex. Annual Review of Neuroscience 27, 649–677 (2004)
7. Norman, D.A.: Categorisation of action slips. Psychology Review 88, 1–15 (1981)
8. Reason, J.: Human Error. Cambridge University Press, New York (1990)
9. Reason, J.: Human error: Models and management. British Medical Journal 320, 768–770 (2000)
10. Leshan, L.: Human computer interface design. Science Press, Beijing (2004) (in Chinese)
11. Fang, H.: Uninhibited processing mechanism of prioritizing selection in preview search. Institute of Psychology, Chinese Academy of Sciences, Beijing (2006)
12. Shihui, H.: The global precedence in visual information processing. Journal of Chinese Psychology 32(3), 337–347 (2000) (in Chinese)
13. Petty, R.E., Desteno, D., Rueher, D.D.: The Role of Affect in Attitude Change. In: Forgas, J.P. (ed.) Handbook of Affect and Social Cognition, pp. 212–229. Lawrence Erlbaurn, Mahwah (2001)
14. Neisser, U.: Cognition and reality: principles and implications of cognitive psychology. W.H.Freeman (1976)
15. Lavie, N., Hirst, A., de Fockert, J., Viding, E.: Load theory of selective attention and cognitive control. Journal of Experimental Psychology: General 133, 339–354 (2004)
16. Lavie, N.: Distracted and confused? Selective attention under load. Trends in Cognitive Sciences 9, 75–82 (2005)
17. Desimone, R., Duncan, J.: Neural mechanisms of selective visual attention. Annual Review of Neuroscience 18, 193–222 (1995)
18. Bjorklund, D.F.: Children's thinking, 4th edn., 119–140, 142–145,162–163, 343–344. Wadsworth/Thomson Learning, Belmont (2003)
19. Theeuwes, J., Burger, R.: Attentional Control during Visual Search the Effect of Irrelevant Singletons. Journal of Experimental Psychology: Human Perception and Performance 24, 1342–1353 (1998)
20. Theeuwes, J.: Top-down Search Strategies Cannot Override Attentional Capture. Psychonomic Bulletin & Review 11(1), 65–70 (2004)
21. Fleetwood, M.D., Byrne, M.D.: Modeling icon search in ACT-R/PM. Cognitive Systems Research 3, 25–33 (2002)
22. Fleetwood, M.D., Byrne, M.D.: Modeling the Visual Search of Displays:A Revised ACT-R/PM Model of Icon Search Based on Eye-Tracking and Experimental Data. Human-Computer Interaction 21(2), 153–197 (2006)
23. Monnier, P.: Redundant coding assessed in a visual search task. Displays 24(1), 49–55 (2003)
24. Bolin, Y.: An experimental study of effects of character spacing under visual interference. Psychological Science 17(3), 129–132 (1994) (in chinese)
25. Van Orden, K.F., Divita, J., Shim, M.J.: Redundant use of luminance and flashing with shape and color as highlighting codes in symbolic displays. Human Factors 35, 195–204 (1993)
26. Wickens, C.D., Andre, A.D.: Proximity compatibility and information display: effects of color, space, and object display on information integration. Human Factors 32(1), 61–77 (1990)