ORIGINAL ARTICLE

Effective Visual Cue for Guiding People's Attention to Important Information on A Computer Display

Yuko MASAKURA, Masayoshi NAGAI and Takatsune KUMADA

Institute for Human Science and Biomedical Engineering, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba Central 6, 1-1-1 Higashi, Tsukuba, 305-8566, Japan.

Abstract: We examined attentional attractiveness of visual cues such as used in presentation graphics. In experiments, we used four different types of visual cues and a visual search task on a computer display. In Experiment 1, it was revealed that two cues (flashing cue and zooming cue) were useful for reducing reaction time to find a target. In Experiment 2, we informed low probability of cue validity to observers. The results showed that the attentional attractiveness found in Experiment 1 could not explained by top-down control of visual attention. Applying these cues to information display would be expected to effectively guide people's attention to important information.

Keywords: *Visual cue, Attentional attractiveness, Visual search*

1. INTRODUCTION

Development of information and communication technology makes information easy to be accessed by multimedia devices such as PC and mobile terminal recently. For example, we can browse web pages which include rich information, especially, home pages have many contents including characters and images to lead people to sub-pages. Development of display technology also leads to an increase in amount of information. For example, a high resolution display would provide us much information at once without scrolling.

People should note that an information display has both important information and not important one. Some of displays such as presentation graphics or web pages include much information, making harder to access important information while ignoring other information. So people might fail to find the important information or access wrong information because of too much information, or it might take long time to find the right one inefficiently. The reason for inaccessibility to important information might be that people cannot ignore other information.

In order to guide people's attention appropriately to important information, visual cues (e.g., flashing circle, zooming square) are used in presentation graphics softwares like Microsoft PowerPoint and Apple Computer Keynote. It has not been studied whether visual cues effectively attracts people's attention to the cued area, although it was just proved that the presentation graphics positively contributed to students' learning [1-4].

If users do not select an effective cue, it does not contribute to attracting people's attention or might even make

important information on a display harder to be found. It is necessary to show behavioral evidence of the cues attracting people's attention in order to make important information on a display easier to be found. Our purpose was to find effective cues for reducing reaction time and increasing accuracy for a visual search task when a target was presented at a cued region. Such effective cues with behavioral evidence may be appropriate for the application to a display in which important information is presented among much other information and could be recommended to use on displays such as presentation graphics.

Previous studies with visual search or cueing paradigm have shown that visual cues capture observers' attention and affect identification and detection of a target. When the target occurs at the cued region, there were performance enhancements for both reaction time [5-10] and accuracy [6, 11, 12]. The visual cues used in most of these studies were a letter or simple bar that covered the limited, small area. Such cues are questionable for the application to guiding people's attention onto the important information in presentation graphics and web pages. Therefore, we used rectangle frames as cues surrounding a larger area than standard visual search task experiments [13, 14] for investigating the effectiveness of visual cues for the practical use on displays such as presentation graphics or web pages.

2. EXPERIMENT 1

We examined the effectiveness of visual cues which increased observers' performances (reducing reaction time and/or increasing accuracy for visual search task) when a target was presented at a cued region. We used four types of visual cues: a static frame, a flashing frame, a moving frame, and a zooming frame. The task of observ-

ers was to find a target among other non-targets. The cue was presented with placeholder, and then remained being presented on a search display after placeholder vanished. If the cues were effective on the target search, its performance would be better when the cue included the target than when did not. We conducted two short experiments (1a and 1b, about 30 minutes each) to keep observers' motivation and arousal level high enough, because we could not properly evaluate the effectiveness of the cues if their motivation and arousal level were low.

2.1 Methods

2.1.1 Observers

15 observers took part in each experiment: 15 males in ranging from 18 to 26 year of age in Experiment 1a, twelve males and three females in ranging from 21 to 28 year of age in Experiment 1b. They had normal or corrected-to-normal visual acuity.

2.1.2 Apparatus

A lap-top-computer (Apple iBook, 600 MHz) controlled stimulus presentation. Stimuli were presented on an LCD display of the computer (14-inch [44.5 x 34.1 deg], 60 Hz refresh rate) at a viewing distance of about 35 cm.

2.1.3 Stimuli

Stimuli were presented against the white background. A fixation, a cue and placeholder, and search items were presented on each trial. The fixation was a black dot (approximately 0.5 deg in diameter). 40 different faces with their holding a phone receiver by their left or right hand (4.3 x 4.3 deg, eight bit gray scale) were used for search items and these images were presented in an array of eight x six. They were presented in random positions in the array, but each quadrant included ten faces. Half of them hold the phone receiver with their left hands and the other half of them with their right hands. Each item of placeholder was averaged image of 40 different faces. 48 averaged face images in the array of eight x six and cue image (described below, Figure 1) were presented as a cue and placeholder.

There were three cue type conditions in each experiment: no cue, flashing cue, and zooming cue in Experiment 1a (Figure 1a) and no cue, static cue, and moving cue in Experiment 1b (Figure 1b). In the no cue condition, a rectangle frame surrounding all the array was presented for 2000 ms. In the flashing, zooming, static, and moving cue conditions, a rectangle frame surrounding each quadrant (four x three array) was presented. In the flashing cue condition, a rectangle frame surrounding one of the quadrants was presented four times for 250 ms in 250 ms inter-stimulus interval (ISI). In the zooming cue condition,

a rectangle frame surrounded all stimuli in the first 500 ms and got smaller every 500 ms, and surrounded one of the quadrants in last 500 ms. In the static cue condition, a rectangle frame surrounding one of the quadrants was presented for 2000 ms. In the moving cue condition, a rectangle frame was presented in each of the four quadrants for 500 ms in clockwise order. That is, except for the no cue condition, visual cue surrounded one of the four quadrants of a screen at the last 500 ms of 2000 ms cue display. The total presentation duration of the cues was 2000 ms with placeholders. Search items were not presented at that time. The cue at the last 500 ms remained on next search display with face stimuli until the observer's response. This quadrant which the rectangle was presented for the last 500ms of 2000ms cue display was defined as the cued area. In the flashing cue and static cue conditions the probability of presenting a cue in each quadrant was equal (25%), and in the zooming cue and moving cue conditions that of presenting a cue at last 500 ms was equal (25%). The probability of presenting a target face in each quadrant was also equal (25%). Thus, the probability that the target face was presented in the cued area was 25% (valid trial) of all trials, and the probability that the target face was not presented in the cued area was 75% (invalid trial). Note that in the no cue condition the cue surrounded all the array and thus always included the target. We supposed the performance in the no cue condition served as control performance of the present search task. We did not inform the probability of the cue validity to observers.

Figure 1: Cue type conditions in each experiment.

(a) Experiment 1a and 2a. (b) Experiment 1b and 2b.

Figure 2: Time course of stimulus presentation in experiments.

2.1.4 Procedure

Observers were asked to search a familiar face (his/her friend's face) among unfamiliar faces and press the key corresponding to the side of hand with the phone receiver as soon as possible, but maintained a high accuracy level. Each cue type condition of 32 trials was blocked and performed randomly across observers (32 trials x 3 cue type conditions). Each trial began with the presentation of a fixation point at the center of the screen. After observer's hitting a space bar, the cue and placeholders were presented for 2000 ms. Then, only placeholders were replaced by stimuli for visual search, and the stimuli and the cue remained on the screen till response by observer's decision.

2.2 Results and Discussion

Table 1 and 2 shows mean reaction times and accuracies in each condition. Differences in reaction time and accuracy were calculated between the experimental conditions (flashing, zooming, static, and moving cue conditions) and the control condition (no cue condition) for each trial and for each observer. Figures 3 and 4 show mean difference in reaction time and accuracy collapsed in valid (white bar) and invalid (gray bar) trials, respectively. The error bars indicate the standard error. If a visual cue attracted one's attention in the cued area other than the un-cued area, the mean difference in reaction time in valid trials in the experimental conditions should be shorter than that in the no cue condition. Moreover, the mean difference in reaction time in invalid trial in the experimental conditions should be longer than that in the no cue condition, because one's attention was attracted in the cued area and thus the visual processing in the un-cued area should be very inefficient. The same kind of performance improvement should be also observed in accuracy for valid trial in the experimental conditions against the no

cue condition, but degraded performance for invalid trial.

This trend of performance change against the no cue condition was shown in reaction time in the flashing and zooming cue conditions (Figure 3a), but little in the static and moving cue conditions (Figure 3b). In accuracy, this trend was not observed in any condition (Figure 4). The mean differences in reaction time were analyzed for a 2 (cue type) x 2 (cue validity) repeated measures analysis of variance (ANOVA) in Experiment 1a and 1b. The main effect of cue validity was significant, $F(1, 14) = 12.93$, $p < .01$, in Experiment 1a but not in 1b, and no main effect of cue type nor interaction in both Experiment 1a and 1b. The mean differences in accuracy were analyzed in similar ways, but neither main effect nor interaction was found. This is because the accuracy hit the ceiling and almost 100%. These results indicated that the flashing cue and zooming cue effectively controlled observers' attention in the cued area and not in the un-cued area, but the static cue and moving cue did not.

Two bottom-up factors could be related to whether visual cues attract observers' attention in the cued area or not. The first one is multiple onsets, and just one onset of visual cue with no other transient signals could be weak for capturing observers' attention for long period (reaction time was about 3-5 second). The second one is that cue includes the target area during the cue presentation like the flashing cue and zooming cue.

In addition to these bottom-up factors, we have to consider a potential top-down factor in the present experiment. In this experiment, we did not inform the probability of the cue validity to observers, and it was unclear whether observers noticed the cue validity was not so high (25%) or misunderstood it was high. Therefore, the present results might reflect the influence of observer's knowledge on the cue validity as well as the bottom-up

Table 1: Mean reaction times and SEs in the experiments (s).

condition	no cue	flashing cue		zooming cue		no cue	static cue		moving cue	
		valid	invalid	valid	invalid		valid	invalid	valid	invalid
Experiment 1a	3.82	3.21	4.23	3.27	4.71	1b	3.51	3.15	3.42	3.44
(SE)	(0.48)	(0.48)	(0.39)	(0.41)	(0.65)		(0.33)	(0.29)	(0.27)	(0.27)
Experiment 2a	3.36	2.35	3.75	2.72	3.73	2b	3.75	3.84	3.51	3.45
(SE)	(0.40)	(0.26)	(0.32)	(0.31)	(0.37)		(0.42)	(0.43)	(0.37)	(0.38)

Table 2: Mean accuracies and SEs in the experiments (%).

condition	no cue	flashing cue		zooming cue		no cue	static cue		moving cue	
		valid	invalid	valid	invalid		valid	invalid	valid	invalid
Experiment 1a	98.33	97.50	98.06	99.17	99.44	1b	99.17	98.33	98.89	97.50
(SE)	(0.70)	(1.56)	(0.80)	(0.97)	(0.44)		(0.37)	(1.14)	(0.49)	(1.34)
Experiment 2a	98.54	98.33	97.78	97.50	98.89	2b	97.71	99.17	98.61	97.50
(SE)	(0.52)	(1.14)	(0.69)	(1.81)	(0.64)		(0.71)	(0.83)	(0.52)	(1.34)

Figure 3: Mean differences in reaction time between the experimental conditions and the no cue condition. (a) Experiment 1a. (b) Experiment 1b.

factors. For example, the attentional attractiveness of flashing cue and zooming cue could occur only when observers thought (i.e., misunderstood) the cue validity was high, but not when they noticed that it was low. In the following experiment, we examined whether the top-down knowledge on the cue validity affected the attentional attractiveness or not.

3. EXPERIMENT 2

In Experiment 2, we examined the effectiveness of visual cues when we informed the probability of the cue validity to observers. If results in this experiment were the same as that in Experiment 1, we could confirm that the attentional attractiveness of the flashing cue and zooming cue resulted from bottom-up factors of stimuli (cues' multiple onsets and its including the target area during their entire durations) but not from the top-down knowledge on the cue validity. Otherwise, we would conclude that the top-down factor also modulated the attentional attractiveness of cues.

3.1 Methods

3.1.1 Observers

15 observers took part in each experiment: eleven males and four females in Experiment 2a in ranging from 19 to 26 year of age, seven males and eight females in Experiment 2b in ranging from 18 to 26 year of age. They had normal or corrected-to-normal visual acuity. No one took part in Experiment 1.

3.1.2 Apparatus and Stimuli

We used the same apparatus and stimuli as used in Experiment 1. As in Experiment 1, there were three cue type conditions in each experiment: no cue, flashing cue, and zooming cue in Experiment 2a and no cue, static cue, and moving cue in Experiment 2b. These experiments were

Figure 4: Mean differences in accuracy between the experimental conditions and the no cue condition. (a) Experiment 1a. (b) Experiment 1b.

conducted with the same probability of the cue validity as in Experiment 1. That is, the probability that the target face was presented in the cued area was 25% (valid trial) of all trials, and the probability that the target face was not presented in the cued area was 75% (invalid trial).

3.1.3 Procedure

We conducted the experiments with the same procedures as in Experiment 1 except for the following. A different procedure from that in Experiment 1 was that we did inform the probability of the cue validity to observers.

3.2 Results and Discussion

Table 1 and 2 shows mean reaction times and accuracies in each condition. Differences in reaction time and accuracy were calculated between the experimental conditions (flashing, zooming, static, and moving cue conditions) and the control condition (no cue condition) for each trial and for each observer. Figures 5 and 6 show mean difference in reaction time and accuracy collapsed in valid (white bar) and invalid (gray bar) trials, respectively. The error bars indicate the standard error.

As in Experiment 1, we discussed the differences between performance changes against the no cue condition in valid trial and in invalid trial. The trend of performance change against the no cue condition was shown in reaction time in the flashing and zooming cue conditions (Figure 5a), but not in the static and moving cue conditions (Figure 5b). In accuracy, this trend was not observed in any condition (Figure 6). The mean differences in reaction time were analyzed for a 2 (cue type) x 2 (cue validity) repeated measures analysis of variance (ANOVA) in Experiment 2a and b. The main effect of cue validity was significant, $F(1, 14) = 13.92, p < .01$, in Experiment 2a but not in 2b, and no main effect of cue type nor interaction in both Experiment 2a and 2b. The mean differences in accuracy were analyzed in similar

Figure 5: Mean differences in reaction time between the experimental conditions and the no cue condition. (a) Experiment 2a. (b) Experiment 2b.

ways, but neither main effect nor interaction was found. These results suggested that the flashing cue and zooming cue effectively controlled observers' attention in the cued area and not in the un-cued area, but the static cue and moving cue did not. That is, there were the same results as that in Experiment 1 even when observers knew that the probability of the cue validity was low. Therefore, the attentional attractiveness of the flashing cue and zooming cue be due to bottom-up factors, but not to top-down knowledge on the cue validity.

4. GENERAL DISCUSSION

Our results suggested that the flashing cue and zooming cue effectively attracted observers' attention in the cued area and not in the un-cued area with visual search tasks. In addition, the results showed that the attentional attractiveness was caused solely by the bottom-up stimulus factors (i.e., cues' multiple onsets and its including the target area during their entire durations), but not by a top-down factor of the observers' knowledge on the cue validity. Therefore, these cues would show a stable effect to attract observers' attention irrespective of their knowledge, and thus are appropriate to applications like the presentation graphics and web page situations. In other words, these cues to the information display such as presentation graphics or web pages expect to guide people's attention to important information effectively. These cues were actually applied to an authoring tool for supporting creation of a multimedia manual for procedure learning [15-17].

One of the effective cues we found in the present study showed multiple onset or flashes. Thus, it is necessary to consider Photosensitive Epilepsy guidelines carefully (e.g., "Guideline on Animation and Other Imaging Techniques" by The National Association of Commercial Broadcasters in Japan [NAB]; limit frequency of flicker is

Figure 6: Mean differences in accuracy between the experimental conditions and the no cue condition. (a) Experiment 2a. (b) Experiment 2b.

five times/sec when it is not red, brightness change in the screen is 20% or less, and don't use flicker continuously longer than two seconds, a guideline on the safety of TV screen images by the Independent Television Commission [ITC]). We thought our flashing cue does not cause a problem, because the frequency is only one time/sec and brightness change was much less than 20% even though the duration is two seconds.

In another paper, we investigated the effectiveness of cues by using other behavioral indexes such as eye movement, and also tried to find effective cues without giving people negative impressions [18]. If a cue effectively attracts people's attention but gave them negative impression such as unpleasantness and dislikeability, it was not appropriate for practical use. Actually, our previous study [18] found that flashing cue and zooming cue did not give people negative impression. At the present moment we have only two cues for effectively guiding people's attention to the important information on a display, but in the near future we would propose the database of variety of the effective cues.

ACKNOWLEDGEMENT

This research was supported by "Assistive technologies to ensure safe and comfortable lifestyles of persons with disabilities", Special Coordination Funds for Promoting Science and Technology, 2004, from Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

REFERENCES

1. A.Szabo, N.Hastings; Using IT in the undergraduate classroom: Should we replace the blackboard with PowerPoint?, *Computers and Education*, 35(3), pp.175-187 (2000).
2. R.A.Bartsch, K.M.Coburn; Effectiveness of PowerPoint

- presentations in lectures, *Computers & Education*, 41(1), pp.77–86 (2003).
3. C.L.Simpson, L.Pollacia, J.Speers, T.H.Willis, R.Tarver; An analysis of certain factors related to the use of PowerPoint, *Communications of the International Information Management Association*, 3(2), pp.73-84 (2003).
 4. J.M.Apperson, E.L.Laws, J.A.Scepansky; The impact of presentation graphics on students' experience in the classroom, *Computers & Education*, 47(1), pp.116–126 (2006).
 5. C.W.Eriksen, J.E.Hoffman; Temporal and spatial characteristics of selective encoding from visual displays, *Perception & Psychophysics*, 12(2-B), pp.201-204 (1972).
 6. C.L.Folk, R.W.Remington, J.H.Wright; The structure of attentional control: Contingent attentional capture by apparent motion, abrupt onset, and color, *Journal of Experimental Psychology: Human Perception and Performance*, 20(2), pp.317-329 (1994).
 7. M.I.Posner; Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, pp.3-25(1980).
 8. M.I.Posner, C.R.Snyder, B.J.Davidson; Attention and the detection of signals, *Journal of Experimental Psychology: General*, 109(2), pp.160-174 (1980).
 9. R.W.Remington, L.Pierce; Moving attention: Evidence for time-invariant shifts of visual selective attention, *Perception & Psychophysics*, 35(4), pp.393-399 (1984).
 10. G.L.Shulman, R.W.Remington, J.P.McLean; Moving attention through visual space, *Journal of Experimental Psychology: Human Perception and Performance*, 5(3), pp.522-526 (1979).
 11. C.W.Eriksen, Y.Yeh; Allocation of attention in the visual field, *Journal of Experimental Psychology: Human Perception and Performance*, 11(5), pp.583-597, (1985).
 12. H.Nothdurft; Attention shifts to salient targets, *Vision Research*, 42(10), pp.1287–1306 (2002).
 13. A.Treisman; Features and objects: the fourteenth Bartlett memorial lecture, *Quarterly Journal of Experimental Psychology*, 40A(2), pp.201-237 (1988).
 14. A.M.Treisman, G.Gelade; A feature-integration theory of attention, *Cognitive Psychology*, 12, pp.97-136 (1980).
 15. H.Shimada, M.Kitajima; Development of an authoring tool for supporting creation of a multimedia manual for procedure learning, *Proceedings of the Sensory Substitution Symposium*, pp.29-32 (2006a).
 16. H.Shimada, M.Kitajima; SMMAPS: Scenario-based Multimedia Manual Authoring and Presentation

System and its application to a disaster evacuation manual for special needs, *Proceedings of The CHI2006 Conference on Human Factors in Computing Systems*, pp.1313-1318 (2006b).

17. H.Shimada, M.Kitajima, M.Nara; Production and evaluation of a learning material for a new pupil to learn how to go to school by SMMAPS, *Proceedings of the Human Interface Symposium 2006*, pp.755-760 (2006).
18. Y.Masakura, M.Nagai, T.Kumada; Relationship between impression and attentional attractiveness of visual cues, *Journal of Japan Society of Kansei Engineering*, 7(3), pp.517-523 (2008).

Yuko MASAKURA

Yuko Masakura is a research staff at Center for Hyper Media Research, Tokyo Polytechnic University since 2006. She graduated from Perceptual Sciences and Design Engineering, Yamaguchi University and received Ph.D. degree in 2005. Then, she was a research staff at Institute for Human Science and Biomedical Engineering, National Institute of Advanced Industrial Science and Technology (AIST) until 2006. She is currently engaged in research and development of evaluation method for display based on human vision and Kansei.

Masayoshi NAGAI

Masayoshi Nagai is Research Scientist at Institute for Human Science and Biomedical Engineering, National Institute of Advanced Industrial Science and Technology (AIST). He received Ph.D. in Psychology from Kwansei Gakuin University, Japan in 2002. He was Project Leader of JSPS-CIHR Japan-Canada Joint Health Research Program, from 2006 to 2008, Visiting Postdoctoral Research Fellow at Department of Psychology, McMaster University, Ontario, Canada, from 2003 to 2005, JSPS Postdoctoral Research Fellow at Department of Intelligence Science and Technology, Kyoto University, Kyoto, Japan, from 2002 to 2005, and JSPS Research Associate for The Research for the Future Program at Department of Intelligence Science and Technology, Kyoto University, Kyoto, Japan, from 2000 to 2002. His research interests include motion perception, face cognition, social interactive behaviors with techniques of psychophysics, brain imaging, etc.

Takatsune KUMADA

Takatsune Kumada is a Group Leader of Cognition and Action Group at Institute of Human Science and Biomedical Engineering in National Institute of Advanced Science and Technology (AIST), Tsukuba, Japan, since 2001. He is currently engaged in psychophysical and brain-imaging studies on basic cognitive functions, such as attention, executive function and motor control, human-machine interface evaluation of products for young and older adults, and neuropsychological studies of the basic cognitive functions with brain-damaged patients and brain-tumor patients. He is also interested in the relationship of these cognitive functions with affective aspects of human processes, including Kansei.