Preference distorts visual space

Miho Kitamura*, Yousuke Kawachi†, and Jiro Gyoba††
*Waseda University, Tokyo, Japan
E-mail: suzmiho@lab.ntt.co.jp Tel: +81-3-5286-3335
†Kansei Fukushi Research Institute, Tohoku Fukushi University, Sendai, Japan
E-mail: kawachi@tfu-mail.tfu.ac.jp Tel: +81-22-728-6085
††Tohoku University, Sendai, Japan
E-mail: gyoba@sal.tohoku.ac.jp Tel: +81-22-795-6043

Abstract—**We investigated whether visual spatial processing can be affected by the degree of preference for paintings. Firstly, the participants were required to manipulate a mouse and point to the location of the target that appeared at the periphery, following the paintings presented at center. After completing this task, the participants judged their preference for each painting on a five-point scale. The results showed that the spatial orientation of the targets was significantly biased towards the center when the highly likable paintings were presented, while the biases decreased in the case of the dislikable paintings. Additional experiments showed that these biases were not attributed to physical features of the paintings. These findings indicate that the subjective preference for visual stimuli potentially distorts our visual field and modulate our pointing performance.**

I. INTRODUCTION

When we find a favorite object, our visual attention is strongly captured by it, and we may then desire to approach the object. Thus, subjective preference drives our behavior in real life. In this study, we explored the specific perceptual behavior that occurs while observing preferred objects.

Previous researches on subjective preference showed there are unique perceptual processing sensitive to preferred objects. For example, observers gaze longer at what they choose in the preference decision task [1][2], attractive face captured attention even in peripheral vision [3] and were better pursued in visual tracking task [4]. Those findings imply that there is a strong linkage between the subjective preference and visual processing.

In this study, we explored that visual preference modulate spatial visual processing. When the eyes are captured by preferred objects, what was the nature of the spatial visual processing of visual field? Although no researches examined the effects of preference on the spatial visual processing directly, there are some related studies so far. Previous research reported the interaction between the motivation and the spatial vision processing. Motivational states modulate spatial visual processing, especially for scope of attention [5][6][7]. Those previous researches showed that high approach motivation (e.g., desire) narrows the scope of visual attention, while low ones broaden the spatial visual attention. From an ecological point of view, it would make sense to modulate attentional scope. As individuals attempt to approach the desired objects, they have to shut out irrelevant stimuli. These results imply that the different motivational states distort the visual space in a different form. Concerning those previous findings, it is highly likely that subjective preference including highly motivational factor plays an important role for the spatial visual processing in the whole visual field.

In the present study, we examined how viewing preferred objects modulates the spatial visual processing of whole visual field. We used a location bias as a measure of the modulation. In general, objects transiently presented in the retinal periphery are reproduced closer to the retinal centre. This is called 'foveal bias' [8][9]. The distortion of location in peripheral target implies the compression of whole visual space [10]. If preference has an influence on spatial visual processing, the location bias of the peripheral targets would be changed depending on the degree of the preference for the objects presented at center.

The goal of the present study was to determine whether preferred objects modulate the location bias, that is, distortion of location. In Experiment 1 and 2, the spatial location of the targets in the peripheral field was examined in viewing preferred paintings in foveal vision. We found that preferred paintings strongly distorted location of targets toward the center, compared to disliked and non-affective ones. Then, in Experiments 3 and 4, we examined the possibility of other factors (e.g., luminance, stimulus size) affecting the location bias, and we found that the bias of the target can be attributed to preference, and not to various physical features of the paintings.

II. EXPERIMENT 1

In Experiment 1, we explored the influence of preference on spatial visual processing, especially on location bias. We manipulated the preference valence of a painting (dislikable, neutral, and likable) that appeared at center and measured the effect of the preference on a pointing response of a target location. We predicted that if preference has an important role for the spatial visual processing, the presence of a likable or dislikable picture would result in stronger location biases than a neutral picture

A. *Participants*

Sixteen university students (8 females) participated in Experiment 1. They all had either normal or corrected vision.

B. *Stimuli and Designs*

The stimuli were presented using Matlab Version 6.5.2 (The MathWorks) and Cogent2000/Cogent Graphics (Wellcome Department of Imaging Neuroscience, http://www.vislab.ucl.ac.uk/cogent.php). The participants viewed the stimuli on a flat-screen 22-inch color monitor (SONY GDM-F520; 1600×1200 pixels; 75 Hz).

Ninety-six paintings were randomly selected for each participant from the 1340 paintings used in the study of Kawabata & Zeki (2004). Average size of those paintings is 6.30 (SD: 2.35) x 6.36 (SD: 0.14) deg. A gray target dot (0.4 deg in diameter; luminance; 16.61 cd/m-2) was randomly presented at one of the eight points of either of the two imaginary circles (6.53 or 8.71 deg in diameter). The fixation crosshairs (luminance; 83.62 cd/m-2) subtended 0.45 deg. in length and 0.45 deg in width was centered on the screen. The background was black (luminance; 0.1 cd/m-2).

C. *Procedure*

The participants sat 60 cm away from the CRT display and viewed the display binocularly. A chin-and-head rest was used to stabilize their visual field and to match their eye level to that of the fixation crosshairs. The participants were required to move the mouse cursor (blue dot: 0.4 deg in diameter, luminance: 11.22 cd/m-2) to click the fixation point, which produced the painting stimulus in the center of the screen (Fig. 1). The target dot was randomly presented for 200 ms in one of eight positions (0, 45, 90, 135, 180, 225, 270, 315˚) on either of the two imaginary circles 50 or 250 ms after the painting stimulus onset (SOA 50 ms, 250 ms). After the target and the painting simultaneously disappeared, the mouse cursor (white dot: 0.4 deg in diameter, 83.62 cd/m^2) appeared and the participants pointed to the remembered location of the target using the cursor (this process is hereafter referred to as pointing task). During this task, the participants were instructed to move their eyes as little as possible. Each participant performed 6 training trials before 96 experimental trials. In half the trials the delay between a picture and the target was 50 ms; in the other half the delay was 250ms. The delay for each trial was selected randomly. After finishing the complete set of pointing tasks, the participants judged their liking for each of the paintings used in the task on a five-point scale ('strongly dislike' to 'strongly like') located under the paintings at their own pace (this process is hereafter referred to as the liking judgment task).

D. *Results*

For the pointing task, based on the x and y coordinates of each pointing response, we calculated the eccentricity of subjectively estimated target locations. A displacement score of each pointing was defined as the subtraction of the physical target eccentricity from the estimated target eccentricity. Negative values indicate memory biases toward the foveal vision.

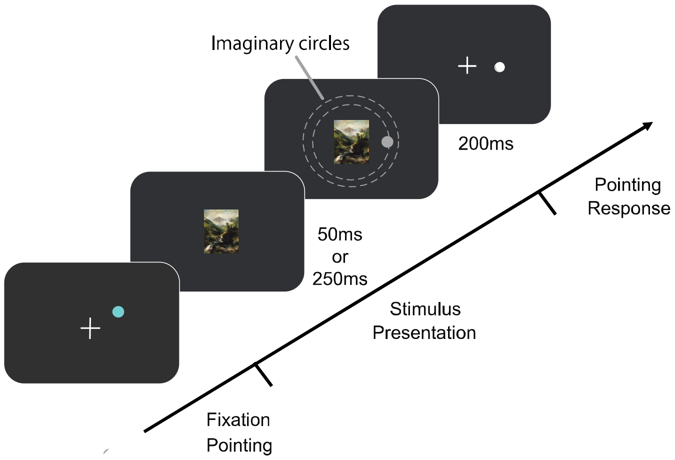


Fig.1 Sequence of the events and stimulus configuration.

For the preference judgment task, the five-point preference scores for each trial were measured and the paintings were classified into three groups based on the scores. The paintings with a score of 1 or 2 were classified as dislikable, those with a score of 3 as neutral; and those with a score of 4 or 5 as likable.

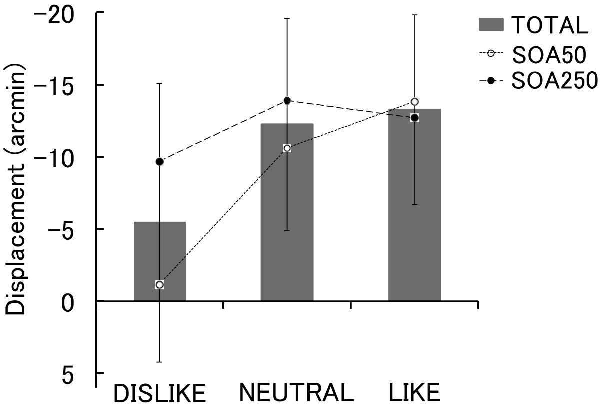
The displacement scores were averaged in each preference set for each participant. A two-way repeated measures ANOVA (3 preference sets (dislikable, neutral, or likable) x 2 SOA (50ms or 250ms)) for those scores showed a significant main effect of the preference sets, F (2, 30) = 4.050, p = .028. There is no significant main effect of SOA (F (1, 15) = 0.839, p = .374) and interaction effect, F (2, 30) = 0.712, p = .498. Mean displacement scores for all participants in three preference sets were plotted in Fig. 2. Post-hoc analyses revealed that the pointing performance was more strongly biased toward the painting stimulus in the likable and the neutral set than in the dislikable set, p < .05, and p < .10 respectively.

E. *Discussion*

The results of Experiment 1 showed that the pointing location of the target was significantly biased towards the foveal vision when the highly preferred and neutral paintings were presented, while the bias decreased for the dislikable paintings. These results indicated that spatial visual processing would be modulated by the extent of preference for stimuli presented in center.

We did not find any significant differences between the neutral and likable sets. These results implied the dislikable set might have specific effects on the location bias. However, we only used artistic paintings as stimuli in Experiment 1.

Therefore, there is the possibility that the neutral paintings are not substantially 'neutral' stimuli, because they would contain some artistic attractive components. In the next experiment, we presented more neutral visual stimuli (e.g. random dots) and investigated the baseline of the location bias in our stimulus configuration.



(dislikable, neutral, and likable). Filled and open circles indicate the scores in 50ms and 250 ms SOA, respectively. Gray bar indicates the combined scores in 50ms and 250ms SOA. Black lines show the standard errors of mean.

III. Experiment 2: Are neutral painting really neutral?

A. *Method*

The experimental design and procedure were the same as those used in Experiment 1, except for the following changes. Ten university students (5 females) participated in Experiment 2. They did not participate in Experiment 1 and all had either normal or corrected vision. The size of random-dot (white dots on a black background, density 50 dots/deg^2, and contrast 96%) is the same size as that of each painting used in Experiment 1 (average size of those paintings: 6.53 (SD: 2.35) x 6.36 (SD: 0.14) deg). The liking judgment task was not conducted after the pointing task.

B. *Results and Discussion*

The average displacement score of all participants in the case of random-dot patches is -1.614 (SE; 7.307) arcmin. This is very close to the physical position of the targets (0 arcmin). To explore the differences between the estimated positions and the physical position (0 arcmin) of the targets while viewing the random-dot patches, a two-way repeated measures ANOVA (2 position (estimated position, physical position) x 2 SOA (50ms or 250ms)) for those displacement scores was conducted. As a result, there is no significance of any main or interaction effect, F (1, 9) = 0.062, p = .809, F (1, 9) = 0.226, p = .645, F (1, 9) = 0.226, p = .645, respectively. These results indicated that simple pointing performance during viewing non-attractive objects was really precise. In addition, the average displacement score in the case of random-dot patches are close to that of the dislike condition in Experiment 1. Those results imply that the location biases are mainly due to the extent of the likeability rather than dislikeability of the paintings. The pointing location for the targets in Experiment 1 would be significantly biased towards the preferred objects appearing at the foveal vision. The stimuli in neutral condition in Experiment 1 would contain some artistic attractive components.

Previous studies reported that locational memory bias has been modulated by stimulus-driven attentional capture [10] [11]. Is the distortion of pointing location in Experiment 1 caused by the preference for the paintings or visual attention dependent on the physical differences between visual stimuli (e.g. luminance or size)? In Experiments 3 and 4 we examined these possibilities. Firstly, in Experiment 3, using luminance-modulated patches, we checked the effects of visual attention on the location biases in our stimulus configuration. Then, in Experiment 4, we asked the same participants as in Experiment 1 to point to the location of the target when they viewed pictorial meaningless stimuli whose luminance and size were almost the same as those of the original paintings.

IV. Experiment 3: Effects of luminance-modulated stimuli on spatial location

It has been reported that spatial location was modulated by stimulus-driven attentional capture [10][11]. However, the stimulus configurations of those studies are slightly different from ours. For instance, objects to capture visual attention were abruptly presented close to the targets in the peripheral visual field. In Experiment 3, we confirmed the effects of attentional capture at foveal vision on the location biases, using the luminance-modulated stimuli.

A. *Method*

The experimental design and procedure were the same as those used in Experiment 1, except for the participants and stimuli. Nine university students (2 females) participated in Experiment 3. They did not participate in any other experiments and all had either normal or corrected vision. We prepared three luminance-modulated patches (Low: 7.20 cd/m^2, Middle: 38.56 cd/m^2, High: 69.02 cd/m^2). The size of all patches was 6.53 x 6.36, which was the average size of all paintings used in Experiment 1. The preference judgment task was not conducted.

B. *Results and Discussion*

Mean displacement scores for all participants in three luminance-modulated patches were plotted in Fig. 3. A two-way repeated measures ANOVA (3 luminance-modulated patches x 2 SOA) for those scores showed significant main effects of SOA and luminance, F (1, 8) = 7.46, p = .026 and F (2, 16) = 5.22, p = .018, respectively. Post-hoc analyses revealed that in High and Middle luminance patches, rather than in Low patches, pointing responses were found to be more biased toward the center, p < .05, and p < .05 respectively. The results suggest that higher luminance onset can capture visual attention more strongly, and that visual attention in foveal vision distorted the location of the targets presented in peripheral vision. These findings are consistent with previous studies that investigated the effects of visual attention on foveal bias [10][11].

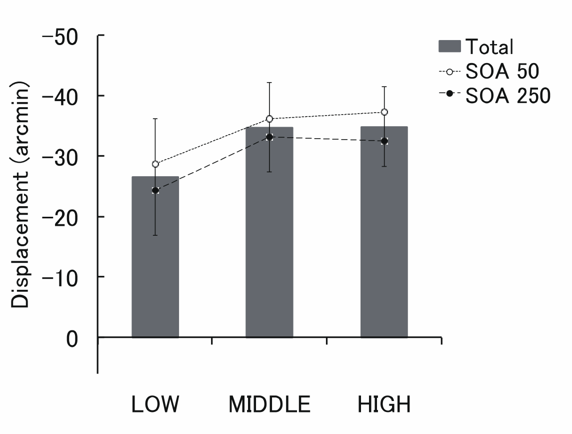


Fig. 3 Mean displacement scores for each of the luminance stimuli (high, middle, and low patches). Filled and open circles indicate the scores in 50ms and 250 ms SOA, respectively. Black lines show the standard errors of mean.

V. EXPERIMENT 4; EFFECTS OF TESSELLATING STIMULI ON SPATIAL LOCATION

The results of Experiment 3 suggested that spatial location was also biased by visual attention captured by exogenous factors, such as luminance of objects. There is the possibility that the location bias of Experiment 1 was caused by various physical differences in visual features (e.g. luminance or size). In Experiment 4, we made tessellating pictures of all paintings used in Experiment 1; those pictures make the pictorial meaningless, while ensuring that the luminance and size are almost the same as those of original paintings. The same participants as those in Experiment 1 were asked to view the tessellating pictures in foveal vision and point to the spatial location of the target in the peripheral vision.

A. Method

The experimental design and procedure were the same as those used in Experiment 1, except for stimuli and liking judgment task. Original paintings used in Experiment 1 were modulated by the stained-glass filter in Adobe Photoshop CS2 (cell size: 7, borderline: 1, strength of lightness: 3). The modulated version of the same paintings presented for each participant in Experiment 1 was presented in the same order. Liking judgment task was not conducted after the pointing task. Based on the preference judgment scores in Experiment 1, each painting was assigned to each preference set (dislikable, neutral, or likable). Average displacement scores during viewing mosaic stimuli were calculated in each set for each participant. Fifteen participants (7 females) identical to those in Experiment 1 participated in Experiment 4. One person (AK) could not join Experiment 4 for a personal reason. We confirmed that location biases in Experiment 1 were also found in all participants except for AK.

B. Results and Discussion

Mean displacement scores for all participants in three preference sets were plotted in Fig. 4. A two-way repeated measure ANOVA (3 preference sets defined in Experiment 1 (dislikable, neutral, or likable) x 2 SOA) for those scores showed no significant main effect of preference sets and SOA, F (2, 28) = 0.012, p = .987 and F (1, 14) = 3.135, p = .098, respectively. There are no significant interaction effects (F (2, 28) = 1.834, p = .178). These results are different from those of Experiment 1 and suggested that the distortion of location in Experiment 1 was not due to the physical differences of luminance and size of the paintings.

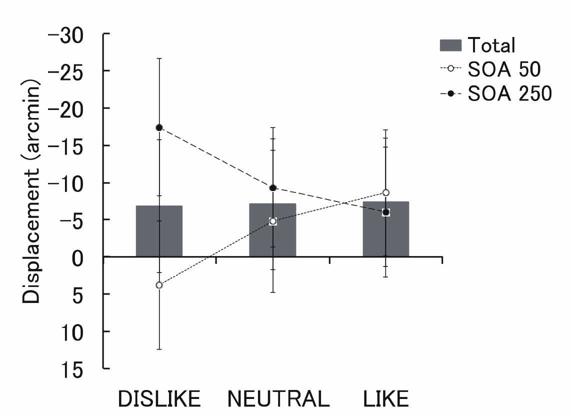


Fig. 4 Mean displacement scores for each of the mosaic picture sets (dislikable, neutral, and likable). Filled and open circles indicate the scores in 50ms and 250 ms SOA, respectively. Black lines show the standard errors of mean.

VI. GENERAL DISCUSSION

The present study is the first to demonstrate that subjective preferences modulate spatial visual processing. The spatial location of the target was significantly biased towards the foveal vision when one viewed the preferred paintings as opposed to the dislikable paintings (Experiments 1 and 2). This location bias could not be explained by just the physical features of paintings (Experiment 3 and 4). These findings suggested that affective signal presented in center vision would exert a strong influence over the spatial visual processing in the whole visual field.

The distortion of the spatial location of the targets presented in peripheral vision implies the compression of visual space [10]. It was only reported that the spatial compression is induced by purely visual phenomena, e.g. saccade [12], not by cognitive or emotional phenomena. Although we need further research, higher human cognitive system including emotion might be one of the factors for the spatial compression.

What is the mechanism responsible for the location bias towards the center in viewing preferred paintings? Previous reports showed that foveal bias was enhanced by visual attention [10][11]. Consistent with these findings, in our Experiment 3, we found that the highly luminant stimuli increased the location biases for peripheral targets toward the center. Meanwhile, in Experiment 4, we confirmed that the present location bias is not accounted by the degree of stimulus-driven attentional capture by luminance differences. Thus, there is the possibility that the preferred objects endogeneously (not exogeneously) captured our visual attention more than the disliked ones did, and that the visual attention induced the strong location biases in peripheral vision.

Another possible reason of the location bias toward the center in viewing preferred paintings is that it was caused by a visuo-motor association, such as approach and avoidance behaviors. The different visuo-motor tendencies were found to be dependent on the emotional valence [13][14][15][16], showing that positive and negative visual stimuli can either facilitate or inhibit approach and avoidance action tendencies. Neurological data also showed the consistent results that viewing ugly paintings activated the brain area that is related to avoidance motor behaviors [17]. Our findings that the participants pointed to the pointing location of the targets toward the preferred paintings would be accounted for by similar linkage between visual and motor processing. Motivational direction operated by preference would modulate our perceptual-motor processing and induce the location biases.

Traditionally, in cognitive science, it has been considered that perceptual processing is independent with affective factor. However, recently, there are many reports that affective factor modulates our visual processing (e.g [18]). In line with the previous findings, our results suggest that visuo-motor processing is under the influences of affective factor including preference. Our results provide empirical suggestions and various application potentialities for visual processing in our daily life, such as visual merchandising. For example, we found that focusing to preferred objects in central vision induces a spatial compression in peripheral vision. This compression might reduce the subjective distance between the objects, suggesting that attractiveness might evoke a perceptual grouping. We believe that our findings might be useful for researchers to develop more sophisticated image or video processing algorithms.

VII. CONCLUSIONS

Here we have demonstrated for the first time that the preference for visual stimuli in the central field potentially induces the spatial compression in visual field. Such a distortion of visual field caused by visual preference opens the path for further investigation of the role of affective factors in the human perceptual motor system. By revealing the intricate relationship between preferences and the perceptual motor system, we might be able to predict a subjective preference for various objects from a pattern of perceptual motor behaviors in future.

ACKNOWLEDGMENT

We appreciate the comments of three anonymous reviewers on an earlier draft of this manuscript.

REFERENCES

[1] S. Shimojo, C. Simion, E. Shimojo, and C. Scheier, “Gaze bias both reflects and influences preference,” *Nature neuroscience*, 6(12), pp.1317-1322. 2003.

[2] C. Simion, and S. Shimojo, “Interrupting the cascade: Orienting contributes to decision making even in the absence of visual stimulation,” *Perception & psychophysics* 69.4, pp.591-595. 2007.

[3] K. Guo, C. H. Liu, and H. Roebuck, “I know you are beautiful even without looking at you: Discrimination of facial beauty in peripheral vision,” *Perception*, 40, pp.191-195. 2011.

[4] W. Chen, C. H. Liu, and K. Nakabayashi, “Beauty hinders attention switch in change detection: the role of facial attractiveness and distinctiveness,” *PloS one,* 7.2. e32897. 2012.

[5] P. Gable, and E. Harmon-Jones. “Approach-motivated positive affect reduces breadth of attention,” *Psychological Science*, 19.5. pp.476-482. 2008.

[6] P. Gable, and E. Harmon-Jones. “The blues broaden, but the nasty narrows attentional consequences of negative affects low and high in motivational intensity,” *Psychological Science*, 21.2. pp.211-215. 2010.

[7] H. Nittono, M. Fukushima, A. Yano, and H. Moriya “The power of kawaii: Viewing cute images promotes a careful behavior and narrows attentional focus.” *PloS one,* e46362. 2012.

[8] S. Mateeff, and A. Gourevich, “Peripheral vision and perceived visual direction,” Biological Cybernetics, 49, pp.111-118. 1983.

[9] S. Mateeff, and A. Gourevich, “Brief stimuli localization in visual periphery,” *Acta Physiologica et Pharmacologica Bulgarica*, 10, pp.64-71. 1984.

[10] B. R. Sheth, and S. Shimojo, “Compression of space in visual memory, ” *Vision Research*, 41, pp.329-341. 2001.

[11] M. K. Uddin, T. Kawabe, and S. Nakamizo, “Attention shift not memory averaging reduces foveal bias,” *Vision Research*, 45, pp.3301-3306. 2005.

[12] J. Ross, M. C. Morrone, & D. C. Burr, “Compression of visual space before saccades,” *Nature*, 386, pp.598-601. 1997.

[13] A. K. Solarz, “Latency of instrumental responses as a function of compatibility with the meaning of eliciting verbal signs,” *Journal of Experimental Psychology*, 59, pp.239-245. 1960.

[14] K. L. Duckworth, J. A. Bargh, M. Garcia, and S. Chaiken, “The automatic evaluation of novel stimuli,” *Psychological Science*, 13, pp.513-519. 2002.

[15] M. Rotteveel, and R. H. Phaf, “Automatic affective evaluation does not automatically predispose for arm flexion and extension,” *Emotion*, 4, pp.156-172. 2004.

[16] K. Roelofs, B. M. Elzinga, and M. Rotteveel, “The effects of stress-induced cortisol responses on approach avoidance behavior,” *Psychoneuroendocrinology*, 30, pp.665-677. 2005.

[17] H. Kawabata, and S. Zeki, “Neural correlates of beauty,” *Journal of Neurophysiology*, 91, pp.1699–1705. 2004.

[18] E. A.Phelps, Sam Ling, and Marisa Carrasco. “Emotion facilitates perception and potentiates the perceptual benefits of attention.,” *Psychological Science,* 17, pp.292-299. (2006):