The Role of Visual Attention in Preference Formation: Urgency Promotes Affective Disengagement

許, 吉

https://hdl.handle.net/2324/4110435

出版情報：Kyushu University, 2020, 博士（システム生命科学）, 課程博士
バージョン：

The Role of Visual Attention in Preference Formation: Urgency Promotes Affective Disengagement

Ji Xu

Supervisor: Professor Johan Lauwereyns

Cognitive Neuroscience Laboratory

In Partial Fulfillment of the Requirements for the Doctoral Degree

in the Graduate School of Systems Life Sciences

Kyushu University, Fukuoka, Japan

June 2020

ETHICS STATEMENT

The protocols for the present study were designed in accordance with the Declaration of Helsinki, and were approved by the Human Ethics Committee of the Faculty of Arts and Science, Kyushu University (Issue No. 201801). Informed consent was obtained in writing from each subject.

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ACKNOWLEDGMENTS

It would not have been possible to write this doctoral thesis without the help and support of the kind people around me, to only some of whom it is possible to give particular mention here.

Above all, I would like to express my deepest and sincere gratitude to my supervisor Prof. Lauwereyns for his invaluable guidance and teaching throughout my entire research life in his laboratory. I truly thank him for giving the opportunity to join Dubito lab where is warm and friendly. He has taught me the methodology to carry out the research in the field of psychology, and continuously helped me to develop my academic skills. It is a great honor to be one of his students and I am extremely grateful for what he has offered. The thesis would not be possible without his patient mentoring, both on academic and personal level.

Second, I would like to thank Prof. Kenji Iramina for offering the facilities of his laboratory, giving me a huge help on conducting experiments. Thanks to his generous, I was able to finish my data collection so smoothly. Also, the opportunity he provided to discuss with researchers from various fields gave me important insights.

Also, I would like to express my appreciation to Prof. Tsuyoshi Okamoto and Dr. Muneyoshi Takahashi for helping me with the procedure of ethic application, and their valuable comments and suggestions on my research, which have given me in preparing the experiment.

Special thanks go to Dr. Noha Mohsen Zommara who has accompanied with me through the hard time of my research, as research colleague and friend. Her kindness and generous supports giving me strength necessary to overcome the difficulties.

I am grateful to all my friends and lab members in both Dubito and Prof. Iramina laboratory, for their assistance, encouragement and collaboration. I also must thank my families who supported and stayed by my side all the time.

Last but not the least, I would like to acknowledge the ASSURAN international scholarship foundation for their financial support during my study at Kyushu University.

General Introduction

Attention, as a selective process, has been studied for decades in various aspects, including its mechanism and effects on perception, the interaction of eye movements, the modulation in neurosciences and so on. It is important to characterize distinct attentional systems not only because it allows us to process the vast amount of information that we confronted in daily life, but also because of its non-negligible effects on our decision-making. It has been known that our attention (or visual attention) can be allocated by moving eyes toward a location (i.e., overt attention, like gazing) or by attending to an area in the periphery without an actual eye movement (i.e., covert attention). In the field of research on visual attention, a well-established paradigm, namely spatial-cueing paradigm, provided a very successful approach to study the pre-cueing effect on allocation of attention (Posner 1984). According to the theory, under specific condition (i.e., different length of time interval between cue and target), our attention that is drawn by a cue could either facilitate or inhibit our decision-making. By utilizing the cueing paradigm, it assisted to develop a better understanding of attentional shift in many aspects. Yet, most of the published articles have focused on the selection of stimuli in perceptual processing, little is known about the role of visual attention in preference formation.

The term of preference formation, on the other hand, is generally used to mean the process of evaluative judgement in the sense of liking or disliking. This kind of evaluative decision-making is thought to be subjective, dependent on an individual's experience and memory as well as the current environment (Stevens, 2008). Previous researches had proved that the preference can be modified by external factors such as the exposure frequency (known as mere exposure effect) and the looking time, in the process of decision-making. One recent influential study found a phenomenon called as "gaze cascade" effect which suggested that the length of looking time correlates to preferential decisions. To be more specifically, the pattern of the eye data in a preferential task indicated that the more you look at one item the more likely you are to develop a preference for it. Here, the implication is that drawing attention to an object have an influence on the "liking" decision for that object. Thus, a reasonable inference is to assume that our preference could be affected by the modification of the attentional cue, which has an impact on the orientation of attention.

Additionally, there are clear evidences that people have different attitude towards positive versus negative information, and the impact from information of different nature is also varied. Therefore, taking account of the valence of the cue in spatial cueing paradigm should provide a more integral view into the cueing effect on choice.

In the light of the above mentioned, the main purpose of the current project is to explore the effect of visual attention on the preference formation by applying a tightly controlled spatial cueing paradigm. The dissertation contains of two main parts. In part 1, a behavioral experiment was carried out to examine the preference for food images. The experiment in this part is designed not only for investigating the effect of cueing on preference, but also building a practical paradigm for eye-tracking experiment. In this part, different natures of digital images (dot or face-logos) were used as attentional or emotional cue in a two-alternative forced choice (2AFC) preferential task. Four sessions that combined two kinds of cues and two different stimulus onset asynchrony (SOA) were conducted for all subjects to test and verify both the “facilitative” and “inhibitory” cueing effect on preference. The results provided several important implications for understanding the interaction of attention and evaluative decision-making on the behavioral level.

To gain a better understanding of the unclear relationship between gaze (visual attention) and preference formation, four further eye-tracking experiments were designed in part 2, basing on the experiment and result in the first part. Besides, in consideration of the two distinct lines of researches, one on the cueing effect on visual attention, and one on the role of gaze cascade in preference formation, two opposing hypotheses regarding the mechanism in between attention and preference formation were raised and compared in this part. In order to perform a well-controlled study, the length of time interval of the paradigm was set to elicit inhibition of return (IOR: inhibitory effect), and the stimuli of cue contained more clear features. Moreover, two different time constraints on response were also applied in part 2 to investigate the factor of urgency in preference formation.

The afterword, as the last body of the main thesis, summarized all the findings from the current project, as well as giving an overall discussion on the limitations and concerns of experiments had been done. In the end, future works that inspired by the findings in this project are mentioned with my own opinion and view.

PART 1

Effects of Attentional and Emotional Cueing on evaluative Decision-making for Food

Abstract

Although several important theories have suggested that the length of looking time correlates with decision-making on preference, previous research has not considered the effect of visual attention (cueing) on preference formation. In this part, we aim to explore whether attentional and emotional cues influence the preference decision-making among different food choices. A strictly controlled spatial cueing paradigm was applied: a 50ms onset cue was presented prior to a stimulus display that consisted of two clearly visible food images and the cue could appear at either side. Participants were asked to choose the food image they preferred. To investigate the effect of visual attention (cueing) and emotional priming respectively, a neutral symbol (dot) or an emotional symbol (face logo with a smile or with a sad expression) was presented with 100 ms and 300 ms stimulus onset asynchrony (SOA) in different sessions, in order to either facilitate or inhibit attention to the cued option. The results

showed that people tended to choose the cued image more often with short SOA than with long SOA in the neutral symbol sessions. Additionally, it was found that the face logo images with a smile were chosen more often than those with a sad expression in the case of long SOA, though not in the case of short SOA. The results provide important implications for our understanding of the interaction of visual attention and evaluative decision-making.

1.1. Introduction

Preference has been explained as an individual's attitude towards a set of objects, especially reflected in the process of decision-making (Lichtenstein & Slovic, 2006). The process of making evaluative judgment on the basis of perceived attractiveness has been typically defined as preference formation, which has been also studied in various aspects (e.g., Scherer, 2005). Generally, preference formation, in other words, the comparative evaluation of decision-making, depends on not only an individual's experience and memory (Stevens, 2008), but also the current environment. Several important studies have proven that the different way of presenting choice options influences human decision-making (e.g., context effects, framing effects); however, most of the previous studies have focused on the processing of perceptual decision-making (e.g., with the requirement of detecting a target), instead of decision-making on preference.

On the other hand, an influential study on preference formation conducted by conducted by Shimojo and colleagues have generated a "Gaze Cascade Effect" hypothesis to explain how subjects construct decision-making on preference (Shimojo et al., 2003). In an experiment involving the free choice of the more attractive face from a pair of face pictures, the researchers found that the selected face was fixated longer than the unselected face, especially in the period of 600 ms leading up to the actual choice. The researchers referred to this phenomenon of gaze shifting and gaze bias to the ultimate preference choice as a “gaze cascade” effect. Not only the study done by Shimojo and colleagues, but also several subsequent studies have demonstrated that the subjects indeed made more gaze fixations toward the option they eventually chose (Nittono & Wada 2009; Glauckner and Herbold, 2011; Glaholt & Reingold, 2012). In addition, as a follow-up study, Bird and colleagues developed the paradigm further and found an exposure effect on preference formation (Bird et al. 2012), in line with the classic study by Zajonc (1968). On the basis of those previous studies on preference formation, it is clear to state that the gaze is actively involved in the preference formation and one could conclude that people tend to gradually commit towards a choice by spending more time looking at it.

In parallel, in the area of research on visual attention, the spatial-cueing paradigm has been a very successful approach to study how different types of cues may influence the allocation of attention (Posner 1984). For instance, with simple peripheral stimuli as cues (e.g., a flash of light, or the outline of a square), subjects tend to respond faster and more accurately to subsequent targets at the location of the cue than at an uncued location. This kind of cueing effect particularly happens with short time delays between the cue and the target, which is also described as stimulus onset asynchrony (SOA). Nevertheless, the effect from peripheral cueing would turn to inhibitory when the time interval is longer (i.e., response to the cued targets becomes slower and less accurate; see Posner & Cohen, 1984; Handy, Jha, & Mangun, 1999). This kind of function has been defined as inhibition of return (IOR), and is often attributed to a process of re-orienting, away from the originally attended location (Klein, 1988 & 2002; Pratt, Kingstone, & Khoe, 1997; Tipper, Weaver, Jerreat, & Burak, 1994). In other words, our visual attention would be withdrawn from the cued location after it has been captured by the peripheral cue in a long SOA condition, which demands an additional process (and extra effort) when the task requires to return to the previous location, in spite of a facilitation caused by the attention residing in short SOA condition. Thus, the effect of peripheral cueing on the orienting of attention should be divided in opposing mechanisms of facilitation and inhibition, occurring at different moments in time. By manipulation the SOA, then, it should be possible vary the extent of visual attention to different portions of the visual field.

Considering the finding of a relationship between preference formation and looking time, on the one hand, and Posner’s study on visual attention, it is reasonable to question the interaction between visual attention, particularly with respect to the orienting of attention by different cueing, and preference formation. One could argue that, if the length of looking time correlates with the likelihood of choosing a certain option (Shimojo et al., 2003; Bird et al., 2012), and if visual attention works on the attentional duration via cueing effects, it should be possible to manipulate people's preference choice through manipulating their orienting of attention. To explore the role of visual attention of cueing in preference formation, we therefore conducted our experiment based on the well-established Posner spatial-cueing paradigm, using food images as our stimuli for evaluative decision-making. Since the different cueing effects occur in perceptual decision-making tasks through attentional shifting, and given the possible relationship between cueing and looking time, we speculate that a similar cueing effect might occur on the processing of evaluative decision-making (i.e., preference formation). Consequently, we applied an attentional cueing condition with a neural symbol (filled white dot) with different SOA of 100 ms and 300 ms (i.e., short and long time delay) to test whether a cue influences the subjects' preference. We predicted a similar result as in perceptual decision-making tasks, that is, people would tend to choose the cued food images more than uncued images in the short SOA condition, but would tend to choose the uncued images in the long SOA condition, when they are required to make preference choices. Furthermore, we used a second type of cue to investigate whether an emotional priming effect might be observed in the preference formation. We used a pair of face logos (smiley and sad) as cues in both short and long SOA conditions. Besides the same predictions with respect to the cued versus uncued choice tendency as in the neutral dot cueing condition, we anticipated a higher probability of choosing images cued by a smiley face, whereas images cued by a sad face would have a lower probability of being chosen.

1.2. Methods

1.2.1. *Participants.*

A total of 43 undergraduate students (ages of 17 to 27, mean: 21.3) from Kyushu University participated in this experiment. Subjects received either course credits for their participation or a participation fee of 1000 yen. All participants were naïve to the purpose of the experiment and had normal or corrected to normal vision. Written informed consent was obtained before the experiment. Four participants' data were excluded from the data analysis; the remaining 39 participants consisted of 23 Japanese and 16 non-Japanese (mainly from China, Korea and Indonesia), with 20 females and 19 males. Three of the participants were left-handed but giving mouse responses by their right hand, same as the right-handed participants.

1.2.2. *Apparatus.*

The experiment was programmed by using Matlab Psychtoolbox software and was displayed on a (32 cm × 54.5 cm) monitor with resolution of 1920 × 1080. Participants were seated at a viewing distance of approximately 60 cm, and were required to respond by clicking a wired mouse.

1.2.3. *Stimuli Sets.*

The stimuli conditions are presented in **Table 1.1**. To assess the influence from different cueing conditions on preference formation, we applied two types of cue stimulus: the white dot (as neutral cue) and the face logo including smiley and sad face (as emotional cue). In both of cueing experiments, two kinds of stimulus onset asynchrony (SOA) were used to either facilitate attention to the cued option (i.e., short SOA: 100ms) or inhibit attention to the cued option (i.e., long SOA: 300ms), respectively, based on the Posner cueing effect and IOR (inhibition of return) phenomena. The different experimental conditions were marked as "Dot-100", "Dot-300", "Face-100" and "Face-300".

The target stimuli consisted of a total of 480 food images cropped from digital images, including pictures of sweets (i.e., cake, cupcake, donut, ice-cream, muffin, parfait), and main dishes (i.e., bread, fried rice, hamburger, hotdog, Japanese lunch box, pizza, ramen, sandwich); the sets of images were counterbalanced in each experimental session. To minimize the visual differences between choice options, the pair of food images in each trial were always imported from the same category (e.g., two simultaneously presented images were from cake category in the first trial, and hamburger category in the second trial).

Experiment	Dot-100	Dot-300	Face-100	Face-300
Cue type	Dot	Dot	Face logo (smile & sad)	Face logo (smile & sad)
SOA	100ms	300ms	100ms	300ms
Onset Cue time	50ms	50ms	50ms	50ms
Number of Trials	40	40	80 (40 / 40)	80 (40 / 40)
Prediction	C > U	C < U	C > U P > N	C < U P > N

Table 1. 1 Experiment conditions. A total of four experimental sessions included two types of cueing and two different SOAs, referred to as Dot-100, dot-300, Face-100 and Face-300 respectively. The number of trials applied for each type of cue was kept the same. The predictions are listed in the bottom row, indicating which image would be more likely chosen. "C" represents cued image; "U" is for uncued image; "P" is positive (i.e., smiley face); and "N" is negative (i.e., sad face). In general, cued images were predicted to be chosen more than uncued in short SOA conditions, whereas the opposite result was predicted in long SOA conditions. Positive emotional cues would enhance choice as compared to negative emotional cues.

1.2.4. *Task Design.*

A within-participants design with two SOAs (100ms and 300ms) × two cueing conditions (cued and uncued) × two cueing valence (dot and face) was employed. Through the entire set of experimental sessions, participants were asked to compare a pair of food images and choose their preferred one as the goal for each trial. In total, participants were required to make 240 choices (i.e., 80 trials in dot sessions and 160 trials in face-logo sessions, including 80 trials with sad face cues and 80 trials with smiley face cues). The order of the experimental sessions was counterbalanced across participants (i.e., half of participants started from the dot-100 session and the other half started from the face-300 session).

1.2.5. *Procedures.*

Participants were instructed to refrain from eating and drinking (except for water) for one hour before the experiment to ensure that food was a relevant stimulus. A self-reported pre-questionnaire was obtained from the participants about their physical conditions. Before starting the actual experiment, the instructions were explained in detail and a training session was performed to ensure that the participants understood the experiment procedure.

The experiment consisted of four sessions; the trial sequence in each session is presented in **Figure 1.1**. Participants clicked the mouse button to initiate each experimental session. In the experiment, a white cross fixation was always shown on the center of the black screen and participants were asked to lock their gaze on the fixation cross all the time except when the food images were showing. Each trial began with 500 ms of fixation, and subsequently a cue was presented for 50 ms, with a variable cue-target SOA of 100 ms or 300 ms (i.e., time delay of 50 or 250 ms), until the presentation of the target display with two food images. The participants were required to make a preference choice between the two food images by clicking the mouse. The pair of food images was displayed in one of four possible patterns (i.e., up-down, left-right, upper right-lower left, lower right-upper left; see **Figure 1.1**); the cue was presented with equal probability at either of the two food images (e.g., if the food images would appear to left and right side of fixation, the cue could be either on left or right side, but with the same probability throughout the session). The maximum duration for decision-making was 5 s. A paper questionnaire was also presented after each experimental session.

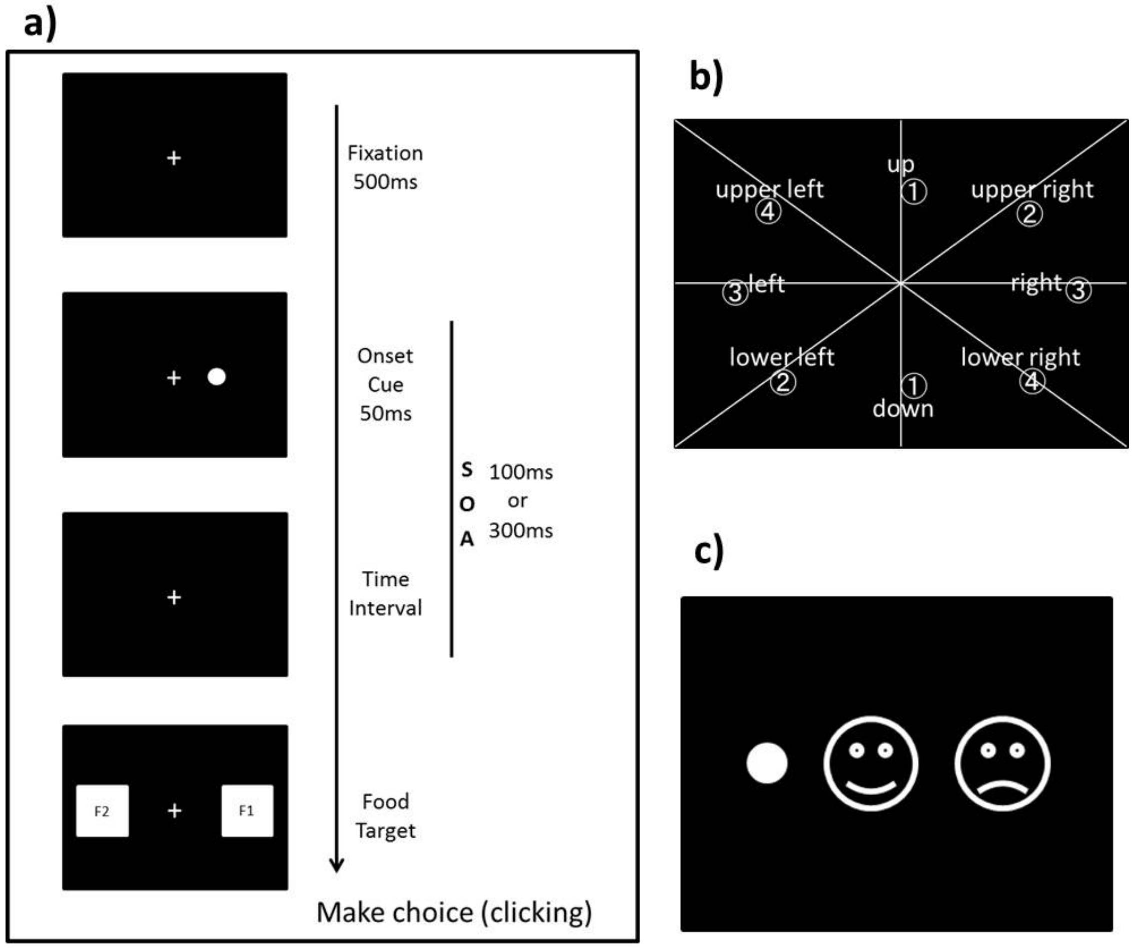

Figure 1. 1 Task design of the experimental sessions. a) Procedure of a trial sequence, based on Posner's spatial cueing paradigm. Two different time intervals were used between onset cue and target stimulus. The maximum duration for making the choice was 5 s. b) The position of the target stimulus: a total of four patterns to display a pair of food images (up-down, left-right, upper right-lower left and lower right-upper left). c) Design of cues: filled white dot (as controlled cue); smiley versus sad face logo (as emotional cueing).

1.3. Data analysis

To examine the cued choice rate in each session experiment, we divided the number of trials in which the cued image was chosen by the total number of trials. This index ranged from 0 to 1; the higher, the more choices for cued images.

$$\text{Cued Choice Rate} = \frac{\text{N(Trials choosing the cued image)}}{\text{N(all performed trials)}}$$

In addition, to analyze the effect of emotional cueing, we used the following equation to calculate cued choice rate for smiley versus sad face respectively:

$$\text{Smiley Face Cued Choice Rate} = \frac{\text{N(Trials choosing the smiley face)}}{\text{N(all performed trials)}}$$

$$\text{Sad Face Cued Choice Rate} = \frac{\text{N(Trials of choosing the sad face)}}{\text{N(all performed trials)}}$$

1.3.1. Counterbalance

To test if there is any significant effect of choice rate between groups (i.e., orders from session 1 to session 4 vs. orders from session 4 to session 1) within sessions, a three-way repeated measures ANOVA was conducted on factors of SOA (100 ms vs 300 ms), cuing condition (cued vs. uncued), and cue type (dot vs. face). The result revealed there was no statistically significant difference within subjects in choice rate response, F (1, 37) = 0.489, MSE = 0.003, p > 0.1, and in groups, F (1, 37) = 0.012, MSE = 0.0, p > 0.1 (**see Appendix 1: Figure A**).

To evaluate the effect of reaction time between groups, a three-way repeated measures ANOVA with the same factors was conducted. The analysis showed there was no significant effect within subjects in response time either within SOA, cuing condition or cue type, p > 0.1, as well as between groups, F (1, 37) = 0.129, MSE = 5.201, p > 0.1 (**see Appendix 1: Figure B**).

1.4. Result

1.4.1. *Attentional Cueing Experiment*

As indicated in **Figure 1.2**, in the dot cueing experiment, the cued image (i.e., the image presented at the same side as the dot cue) was chosen in 51.7% of all the performed trials in the short SOA condition (i.e., Dot-100 session), and with 47.7% cued choice rate in the long SOA condition (i.e., Dot-300 session), respectively. A one-way repeated measures ANOVA was conducted on cued choice rate using a within-subjects factor of SOA (100 ms vs. 300 ms), which revealed a statistically significant effect of SOA, F (1, 38) = 4.785, MSE = 0.031, $p < 0.05$, indicating a higher choice rate of cued image in 100 ms (vs. 300 ms) SOA condition. No significant difference between the cued and uncued choice rate was found within each experimental session experiment ($p > 0.1$).

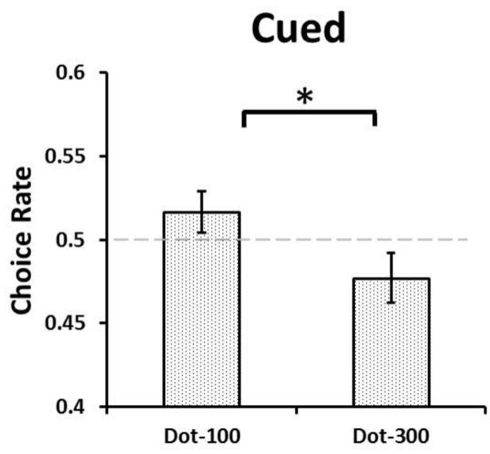

Figure 1. 2 The probability of cued choice in the attentional cueing experiment. The choice rates are shown for the cued image in the Dot-100 session (mean ± SE = 0.517 ± 0.012), and in the Dot-300 session (mean ± SE = 0.477 ± 0.015). A one-way repeated measures ANOVA showed a statistically significant effect of SOA in sessions, F (1, 38) = 4.785, MSE = 0.031, $p < 0.05$.

1.4.2. ***Emotional Cueing Experiment.***

In the face-logo cueing experiment, a statistical analysis from all trials, regardless of the different types of faces, revealed that the choice rates to cued images were almost equal to each other in both the short and long SOA conditions: 49.8% in the 100 ms SOA session and 49.7% in the 300 ms SOA session. There was no significant main effect in each condition, nor between the two conditions (see **Figure 1.3**).

On the other hand, to investigate the effect from different face cues, we divided all performed trials on cued images to smiley cued and sad cued trials to calculate the choice rate of each face logo. As indicated in **Figure 1.4**, the result of the cued choice rate on different face logos showed an interaction effect between conditions, from a two-way ANOVA with factors of SOA (100 ms vs 300 ms) and types of face logo (smiley vs. sad), $F\ (1, 37) = 5.606$, MSE = 0.001, $p < 0.05$. Additionally, a student *T-test* was conducted on different face-logo in each condition, and we found a significant effect of face-logo in the long SOA session, which indicated that the choice rate of smiley cued images was higher than that of sad cued images (smiley: M = 52.1%, SE = 1.1; sad: M = 47.9%, SE = 1.1; $p < 0.05$). No difference on choice rate between smiley and sad faces was found in the 100 ms SOA condition (smiley: M = 50.2%, SE = 1.0; sad: M = 49.8%, SE = 1.0; $p > 0.1$).

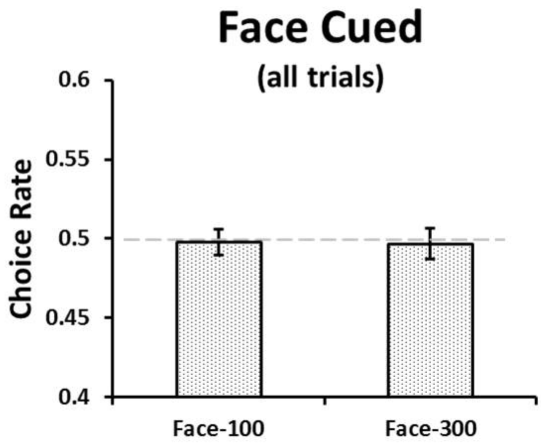

Figure 1. 3 The probability of cued choice from all trials in the emotional cueing experimental sessions. The choice rates of all cued images are presented in the face-100 session (mean ± SE = 0.498 ± 0.008), and the face-300 session (mean ± SE = 0.497 ± 0.010). No significant effect was found from one-way ANOVA analysis; $p > 0.1$.

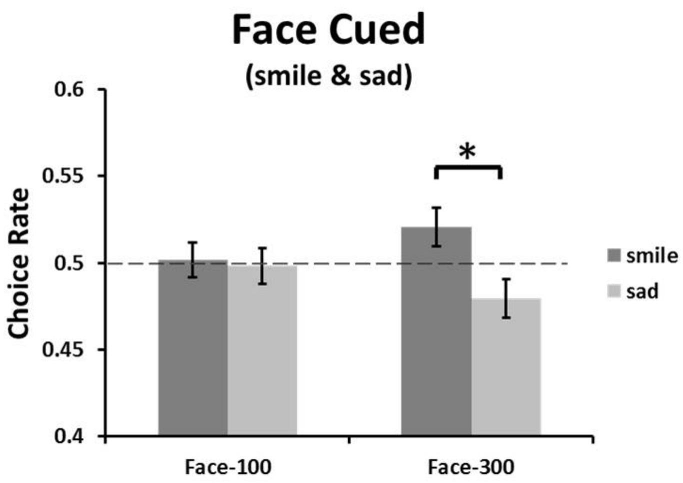

Figure 1. 4 The probability of cued choice varied by different face-logo in the emotional cueing experiment sessions. In the Face-100 session, no significance was found between the choice rate of smiley cued images (mean ± SE = 0.502 ± 0.010) versus sad cued images (mean ± SE = 0.498 ± 0.010). In the Face-300 session, the choice rate of smiley cued images (mean ± SE = 0.521 ± 0.011) was higher than that of sad cued images (mean ± SE = 0.479 ± 0.011), as confirmed by student T-test analysis. A two-way ANOVA revealed an interaction effect between the Face-100 and Face-300 conditions; $p < 0.05$.

1.4.3. ***Reaction time.***

Reaction time was measured as the time taken to click mouse button following food images presentation. The results were excluded if the choice did not be made during 5s. A three-way repeated measures ANOVA was conducted on RTs using within-participants factors of SOA (100 ms vs 300 ms), cuing condition (cued vs. uncued), and cue type (dot vs. face-logo). The results showed there was no significant man effect of cueing condition, nor an interaction between SOA and cue type, $p > 0.1$.

1.5. Discussion

The current study addressed the question of whether our preference decision-making could be affected by manipulating the orienting of attention. To this aim, we presented the neutral dot and emotional facial cues in a tightly controlled spatial cueing paradigm, by asking for a preference choice between a pair of same categorized food images. As per the findings of Shimojo et al. (2003) and the principle of the Posner cueing paradigm, it was expected that images presented at the same side as the cue in a short time interval (i.e., 100 ms SOA) condition would be more likely to be preferred; the opposite result would hold true in the long SOA condition (i.e., 300 ms SOA). The present finding from the dot cueing experiment clearly showed the expected trend: the choice rate of cued images was particularly reduced in the long SOA condition. It indicated a possibility of a bias from visual attention to preference decision-making, and the bias happened most likely because of "*inhibition of return*" (IOR) effect. Since the initial discovery of "*inhibition of return*" by Posner & Cohen (1984), the inhibitory function has often been thought of as a useful phenomenon to explore the effect of peripheral cueing in recent years (e.g., Fox, Russo, & Dutton, 2002; Taylor & Therrien, 2005; Theeuwes & Van der Stigchel, 2006; Stoyanova, Pratt, & Anderson, 2007; Weaver, Aronsen, & Lauwereyns, 2012). Different from old studies, we applied the IOR effect on evaluative decision-making in the present experiment, instead of the typical perceptual decision-making tasks from previous papers. Considering the principle of IOR described in early studies (e.g., Klein, 1988 & 2002; Pratt, Kingstone, & Khoe, 1997; Tipper, Weaver, Jerreat, & Burak, 1994), the result of the present study gave an important implication for the relationship between visual attention and evaluative decision-making; that is, the effect of IOR affects our decision-making not only in perceptual processing but also in evaluative processing, via attention shifting. Moreover, our result may also indirectly associate to the explanation of likelihood and looking time in the gaze cascade hypothesis, namely, more orienting of attention may influence the looking time to the cued target, which in turn affects the preference choice. Interestingly, our result suggest that the influence would be mainly negative, with longer SOA: the cues effectively turn people off the cued images, by inhibiting the return of attention there.

With respect to the result from emotional cueing experiment, however, no significant difference in choice rate was observed from analysis of all performed trials, regardless of the type of face-logo. It indicated an emotional cueing influences the evaluative decision-making not only by attention shifting. The fact that the face-logo cue contains more meaningful features than a neutral dot cue may explain the reason of non-difference result, that is, an emotional cueing plays a role in both processing of attention shifting and emotional priming (or information priming). In other words, visual attention can be affected by emotion, to be more specific, our orientation of attention correlates with emotional expression. Indeed, the relationship between emotion and decision-making has been studied in many aspects since long time ago and it is believed that emotion interacts with evaluation and motivation, irrespective of its own characteristic decision process (Ortega y Gasset 1957; Strongman 1978; Toda 1980). Moreover, the impact could either be positive or negative (Tomkins, 1970). Accordingly, the different findings between the two kinds of experiments could be due to difference in path of processing in general, since it is reasonable to have a more complex conscious processing in the face-logo cueing experiment, with both of attentional and emotional factors.

Another interesting finding from the emotional cueing experiment is the different ratio of choosing cued images with different types of face-logo in the "Face-300" condition. The result revealed a higher choice rate of cued images with smiley face cued than with sad face cued, even though no similar trend was observed in the "Face-100" condition. The possible explanation for the different result in these two sessions could be the less time for detecting or recognizing the face-logo in "Face-100" condition, which has a shorter time delay (50 ms) in the paradigm. Unlike the case of "Face-300", in the "Face-100" session it is more difficult to realize the cue or the content of the cue owing to an extremely short time interval, resulting in insufficient time to complete a recognition process; participants may have realized the cue but in a very rush processing which brought a conflict with the task processing. In addition, compared to "Face-100", "Face-300" showed a significant difference between smiley and sad face-logo. This observation is in line with previous studies (e.g., Tomkins, 1970), suggesting that people tend to choose positive options rather than negative options; in the present study, the positive options were the images cued by the smiley face logo. Additionally, taking into account the IOR effect, it appears that this mechanism of emotional processing interacted the IOR in evaluative decision-making; namely, a positive expression counteracted against the effect of IOR, leading to a higher result compared to the choice rate of smiley cued images in "Face-100"; a negative expression, however, exacerbated the effect with IOR. Thus, the strongest effect observed in the present study is that of a sad face cue at long SOA, effectively a strong negative influence, driving people away from choosing the cued image.

In summary, in the light of the results of the present study, we suggest that visual attention plays an active role to influence the preference decision-making;

furthermore, the "*inhibition of return*" mechanism prominently affects the evaluative decision-making in both attentional and emotional cueing. Several questions remain open for future research, such as whether different types of cue capture different levels of visual attention, and to what extent this would influence the preference decision-making, and the reason for that influence. Also, it remains unclear what is the relationship between gaze and preference choice exactly in cueing paradigm. To address these issues, an eye-tracking study with more strictly controlled cueing paradigm were carried out in next part. The work in part 2 build on the present study to further our understanding of the mechanisms of visual attention in evaluative decision-making.

PART 2

Urgency Promotes Affective Disengagement: Effect from Bivalent Cues on Preference Formation for Abstract Images

Abstract

Although previous research has characterized the important role for spatial and affective pre-cues in the control of visual attention, less is known about the impact of pre-cues on preference formation. In preference formation, the gaze cascade phenomenon suggests that the gaze serves both to enhance and express "liking" during value-based decision-making. This phenomenon has been interpreted as a type of Pavlovian approach toward preferred objects. Decision-making here reflects a process of gradual commitment in which the gaze functions as a precursor to choice; by this account, overt attention produces a necessarily positive, additive effect on the value of the attended object. The implication is that drawing attention to an object should initiate, and therefore promote, preference formation for that object. Alternatively, information-integration models of attention propose that attention produces a

multiplicative effect on the value of the attended object, implying that negative information can impede preference formation. To pitch the gradual-commitment hypothesis against the information-integration hypothesis, we conducted four experiments that combined the spatial-cueing paradigm with a value-based choice paradigm. In each trial in all experiments, subjects were presented with an irrelevant, peripheral pre-cue for a duration of 500 ms, followed by a 500 ms blank, and then a pair of abstract images (one at the pre-cued position; one in the opposite hemifield). The subjects were asked to choose their preferred abstract image by pressing the corresponding button. We manipulated the type of pre-cues (images of faces versus foods; with varying affective associations) and the time constraints (a deadline of 1,500 ms versus self-paced). Overall, the choice data showed a clear pattern of influence from the pre-cues, such that, given a deadline, abstract images were chosen less often if they had been preceded by a pre-cue with a negative affective association (both for face and food images). Analyses of the gaze data showed the emergence of significant gaze biases in line with the subjects' choices. Taken together, the data pattern provided support for the information-integration hypothesis, particularly under urgency. When tasked with a speeded preference choice, subjects showed affective disengagement following pre-cues that carried a negative association.

Introduction

As described in Part 1, in the research of preference formation, Shimojo and his colleagues found a systematic relationship between gaze and preference, called the "gaze cascade," indicating a positive effect of overt visual attention on preference formation (Shimojo et al., 2003). In this eye-tracking study, pairs of images (faces in some conditions; abstract art images in other conditions) were presented on the screen and subjects were required to choose the more attractive one. It was found that subjects' gaze tends to gradually orient towards their final choice, starting from more than half a second before the actual decision. In other words, people appear to commit to their preferred choice by spending more time looking at it. As an explanation for the effect, Shimojo and colleagues suggested that the orienting behavior itself not only expresses the likelihood of choice, but also generates the preference for the item being gazed at, resulting in an enhancement of preference.

The hypothesis of a direct connection between human gaze and preference formation can be characterized as a form of "Pavlovian approach," by which the behavioral orienting serves in effect as a precursor to the choice (Lauwereyns, 2012). Here, we will refer to this proposal as the "gradual-commitment hypothesis." The evidence of a tight connection between looking and liking was shown to be highly reproducible (including in our own laboratory) in a wide variety of conditions (Simion and Shimojo, 2006, 2007; Glaholt and Reingold, 2009; Schotter et al. 2010; Bird et al., 2012; Morii and Sakagami, 2015; Zommara et al., 2018). However, several lines of research suggest that the relationship between orienting behavior and preference formation may be complex, as a function of the nature of the stimuli being processed. Even within the literature on Pavlovian conditioning, evidence indicates that parallel learning systems may be at work, leading to dissociable effects for gaze direction and affective evaluation (Pool et al., 2019). More generally, the orienting behavior in preference formation might involve covert mechanisms of attention in addition to the overt attention, raising the possibility of different types of information integration that do not necessarily equate attention with enhancement of preference formation.

The issue can be specified more formally via an accumulator model of preference formation developed by Krajbich and colleagues (2010). The hypothesis of a direct connection between gaze and preference formation amounts to an additive accumulator model, by which gaze duration necessarily leads to a positive increase in the value of the attended object. Conversely, as indeed anticipated by Krajbich and colleagues, it seems reasonable to hypothesize a multiplicative relationship between attention and value, with increased gain as a function of gaze duration. The implication here is that attention to negatively valued stimuli should hyperpolarize the preference formation in the negative direction, making the attended object less likely to be chosen. Recent work by Gluth and colleagues (2018; 2020) demonstrates the importance of distinguishing between additive and multiplicative accumulator models of preference formation.

The hypothesis of a multiplicative relationship between attention and value is consistent with classic work on the "feature-integration theory of attention" (Treisman and Gelade, 1980) proposing that attention serves a binding function in information processing. Although this theory was proposed with respect to the integration of primitive visual features, later work has expanded the notion of an integrator function of attention to other types of information, including affective features as well as complex or abstract semantic features (e.g., Raymond et al., 2005; Li et al., 2016; Kunar et al., 2017; Scharinger et al., 2017). The corollary of this notion is that attention to an object might lead to either an increase or a decrease in the value of the attended object, depending on the nature of the information being integrated. Thus, drawing attention to negative information with respect to an object would lead to a gradual devaluation of the attended object, whereas positive information would promote the valuation. We will refer to this hypothesis as "the information-integration hypothesis."

To resolve the unclear relationship between attention and preference formation, we performed a behavioral experiment combining the Posner cueing paradigm (for a comprehensive detail of explanation, see introduction in part 1) with an evaluative decision-making task for food images in last part, nevertheless, it is insufficient for understanding the exact attention shift mechanism if only from the behavioral result. Therefore, in this part, a more strictly controlled experiment with both measuring the subjects' manual responses and eye movements was carried out: subjects were presented in each trial with a pre-cue, followed by a pair of abstract art images. While being allowed to move their eyes, as in the gaze-cascade paradigm, the subjects had to select their preferred image by pressing a button. Based on the pilot study (i.e., part 1, also see Xu et al., 2016) to establish appropriate experimental procedures and required statistical power, the timing of the spatial pre-cues was set to elicit inhibition of return: 500 ms pre-cue presentation and 1 s stimulus-onset asynchrony (i.e., SOA) between the pre-cue display and the target display. Here, inhibition of return would imply more attention for the uncued target, and therefore a higher likelihood of choosing the uncued target, as compared to the cued target.

Our present study consisted of four experiments. In the first two experiments, we used images of faces expressing different emotions (happy, neutral, disgust) as pre-cues under two different time constraints: either a deadline of 1,500 ms or no deadline. In the next two experiments, we used images of foods associated with different affective values (either appetitive or aversive) as pre-cues, again with either a deadline of 1,500 ms or no deadline.

For the targets of the preference tasks, we opted in all experiments to use the abstract, unfamiliar shapes ("Fourier descriptors") employed also by Shimojo et al. (2003) in their original gaze cascade study. We chose Fourier descriptors, rather than faces, as targets to avoid non-affective, category-to-category priming effects from the faces used as pre-cues.

Following the "information-integration" hypothesis, it should be expected that positive cues would increase the value of cued objects (and thereby counteract the inhibition of return), whereas negative cues would decrease the value of the cued objects (and thereby further exacerbate the inhibition of return). That is, the valence of the pre-cue should influence the preference formation. In contrast, according to the "gradual-commitment" hypothesis, any influence from pre-cues on the control of overt attention should always promote the preference formation for the item being gazed at, independent of the valence of the pre-cue.

As for the different time constraints (i.e., with or without deadline), we aimed to examine whether urgency modulates the effects of pre-cueing. A number of studies have established that urgency can have a critical impact in various types of decision-making (Rastegary and Landy, 1993; Waller et al., 2001; Suri and Monroe, 2003). Reddi and Carpenter (2000) showed that urgency strengthens the impact of prior bias on perceptual decision-making. Similarly, we anticipated that urgency could strengthen the impact of pre-cues on evaluative decision-making. Thus, regardless of whether pre-cues would promote or impede preference formation, their influence should be larger with a deadline than without a deadline.

Method

Participants.

All subjects were recruited from Kyushu University. In the Deadline and Self-paced Face-cueing experiments, there were in total 28 subjects (22 males and 6 females; with a mean age of 23.0 ± 1.67 years old, 2 left-handed). In the Deadline Food-cueing experiment, there were 32 subjects (16 males and 16 females; with a mean age of 21.1 ± 2.59 years old, 2 left-handed). Another 32 subjects participated in the Self-paced Food-cueing experiment (11 males and 21 females; with a mean age of 21.7 ± 1.87 years old, 1 left-handed). All subjects were naïve to the purpose of the experiment and had normal or corrected to normal vision. The study was conducted in accordance with the ethical principles of Kyushu University and approved by the Human Ethics Committee of the Faculty of Arts and Science. Each subject received either course credit or monetary compensation of 1,000 yen for their participation. Written informed consent was obtained before the experiment.

Apparatus

All visual stimuli were presented on a 23.8-inch full high definition flat-panel-monitor, with a display resolution of 1920 × 1080 pixels. To minimize the head movement by subjects, a chin-rest with a forehead-support was used. The monitor screen was set approximately 62 cm from the chin-rest. Subjects used a keyboard to give manual responses, and their eye movements were recorded by Eye Tribe, an eye-tracking device at 60 Hz sampling rate (The Eye Tribe Aps, Denmark); a system with sufficient reliability for present purposes (Ooms et al., 2015; Wolf et al., 2018; Zommara et al., 2018). To prevent the heat build-up of Eye Tribe, a small universal serial bus (USB) fan was used at the same time.

To record the subjects' eye movements via Eye Tribe, the subjects were asked to focus and follow a dot on the screen for a 16-point calibration (Ooms et al., 2015). After the calibration, the gaze coordinates were calculated through Eye Tribe with an average accuracy of around 0.5° to 1° of visual angle. All events and recordings were controlled through code written in Psychopy (version 1.84.2) (Peirce, 2009; Peirce et al., 2019), including the PyTribe library.

Stimuli

In the Deadline and Self-paced Face-cueing experiments, four different stimuli were used as pre-cues: a white dot (serving as a control) and three different human facial expressions, classified as neutral, happy and disgusted. The face stimuli were selected from the online NimStim Face Stimulus Set (Tottenham et al., 2009). Based on an online questionnaire prior to conducting the experiment (n= 55), we selected the images that were voted as most exemplary for the three facial expressions of neutral, happy and disgusted. All cue stimuli were fixed at 200 × 257 pixels, at a distance of 200 pixels from the fixation cross. The target stimuli consisted of a set of 320 computer-generated geometric figures, including 160 symmetrical figures and 160 asymmetrical figures. The set of figures was drawn by a Fourier Descriptor algorithm (Sakai and Miyashita, 1991; Shimojo et al., 2003). All figures were paired with the same category (i.e., two symmetrical or asymmetrical figures paired together), and in total 320 pairs were made for the two experiments (i.e., 160 for the Deadline experiment and the other 160 for the Self-paced experiment). With the regard to the pairing, each figure was used two times for pairing with two different figures. By this manipulation, we were able to have 320 unique pairs from the set of 320 geometric figures, even though a single figure would be exposed twice to each subject. All target stimuli were fixed at 480 × 360 pixels, at the distance of 300 pixels from the fixation cross. (for stimuli images, see **Figure 2.1**)

In the Deadline and Self-paced Food-cueing experiments, three types of stimuli were used as pre-cues: a white dot (serving as a control) and two different categories of food images, classified as appetitive food cues and aversive food cues. The food images were selected from the database used in another study done in our lab (Ounjai et al., 2018). The database consisted of the FoodCast research image database (FRIDs) (Foroni et al., 2013) with additional non-copyrighted images from the internet (Ounjai et al., 2018). Based on the evaluation scores from our previous study, 160 images were selected as food cues for this experiment: 80 images with the highest evaluation scores were used as appetitive food cues and 80 images with the lowest evaluation scores were aversive food cues. All cue stimuli were fixed at 350 × 350 pixels, at the distance of 257 pixels from the fixation cross. The target stimuli were selected from the same database of face-cueing experiment, but only 240 geometric figures (120 symmetrical and 120 asymmetrical) were used. Similar to the face-cueing experiment, each figure was paired with two different figures to compose 240 unique pairs for experiment. This 240 unique pairs were used in both Deadline and Self-paced Food-cueing experiment. All target stimuli were fixed at 480 × 360 pixels, with the distance of 300 pixels from the fixation cross.

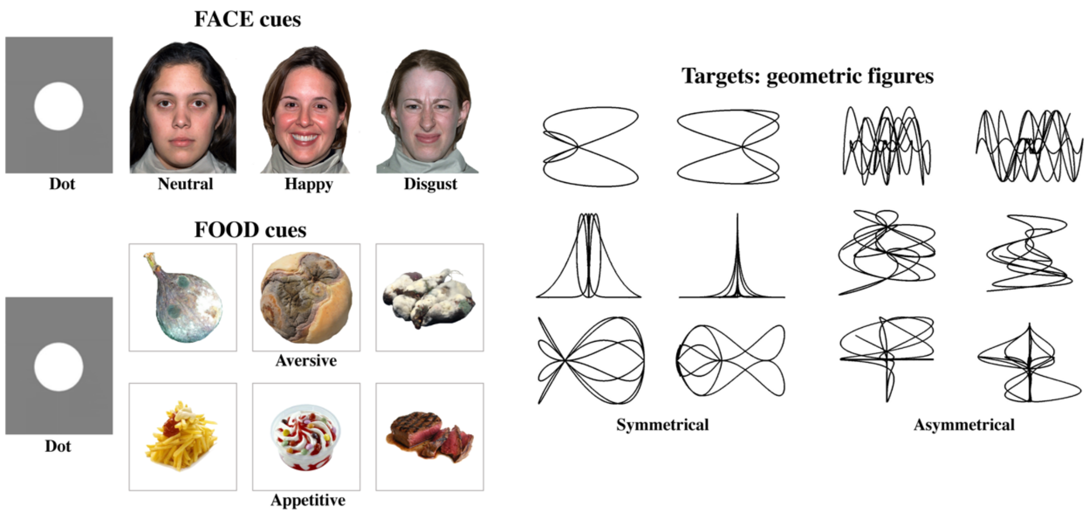

Figure 2. 1 Example of cues and target stimuli. In face cueing experiments, there are four different pictures applied as the cue, including a dot, a neutral face, a happy face and a disgusted face. In food cueing experiments, the cues consist of 3 types: a dot, aversive food images and appetitive food images. The target stimuli for all experiments are geometric figures, including symmetrical pairs and asymmetrical pairs.

Procedures

In the Deadline Face-cueing experiment (DLFC), there were 4 consecutive blocks of 40 trials. Before starting each block, subjects were asked to fix their head on the chin-rest for the calibration (Ooms et al., 2015). After the subject's eye positions were calibrated, the subject was instructed to keep their posture without any big movement until the end of the trials. Short breaks were allowed between the 4 blocks. **Figure 2.2** shows the sequence in each trial. A trial started with the presentation of a fixation cross at the center of the screen for at least 500 ms. Subjects were asked to gaze at the fixation until a cue appears. The subjects' gaze was recorded online and checked in real-time to confirm whether the subject was looking at the fixation cross. After the fixation, a spatial cue for 500 ms would appear on either the left or right side of the fixation. This was followed by a 500 ms time-interval after the cue. Finally, a pair of target images was presented, one on the left and one on the right side of the screen. Subjects were asked to choose the image they preferred within 1.5 s by using their index fingers to press either the left or the right button on the keyboard. The target images disappeared once the subject pressed the button to indicate their response, or when the time reached 1.5 s. A warning message ('TOO SLOW') was given as feedback for 1 s if the subject failed to give a response before the deadline. A blank screen for 2 s was set for the inter-trial interval (ITI) between each trial.

In the Self-paced Face-cueing experiment (SPFC), the procedures were the same as in DLFC except for the time constraint for responding. In SPFC, the subjects were instructed to compare the two target images carefully and give their response without any time pressure. Since there was no deadline, there were never any warning messages for being too slow in SPFC.

Both DLFC and SPFC had in total 160 trials, consisting of 20 repetitions of 8 conditions, with 4 levels of cue type (Dot, Neutral face, Happy face, Disgusted face), and 2 levels of spatial cueing position (either on the left or on the right side of fixation). The order of trials was pseudo-randomized to ensure that each block of 40 trials contained 5 repetitions of each condition. Before the experimental task, a training session of 20 trials was set for participants to practice. Since DLFC and SPFC were conducted with the same subjects, we counterbalanced the order of the experiments across subjects (i.e., 14 subjects started with the deadline experiment and the other 14 subjects started with the self-paced experiment).

In the Deadline Food-cueing experiment (DLFD), the experimental flow and trial sequence were the same as in DLFC: Subjects were required to select their preferred image within a deadline of 1.5 s. The experiment had in total 240 trials, consisting of 4 consecutive blocks of 60 trials. There were 40 repetitions of 6 conditions, with 3 levels of cue type (Dot, Appetitive food, Aversive food), and 2 levels of spatial cueing position (either on the left or on the right side of fixation). The order of trials was pseudo-randomized to ensure that each block of 60 trials contained 10 repetitions of each condition. Before the experimental task, a training session of 20 trials was set for participants to practice.

In the Self-paced Food-cueing experiment (SPFD), the procedure was the same as in DLFD except that there was no time limit for the response.

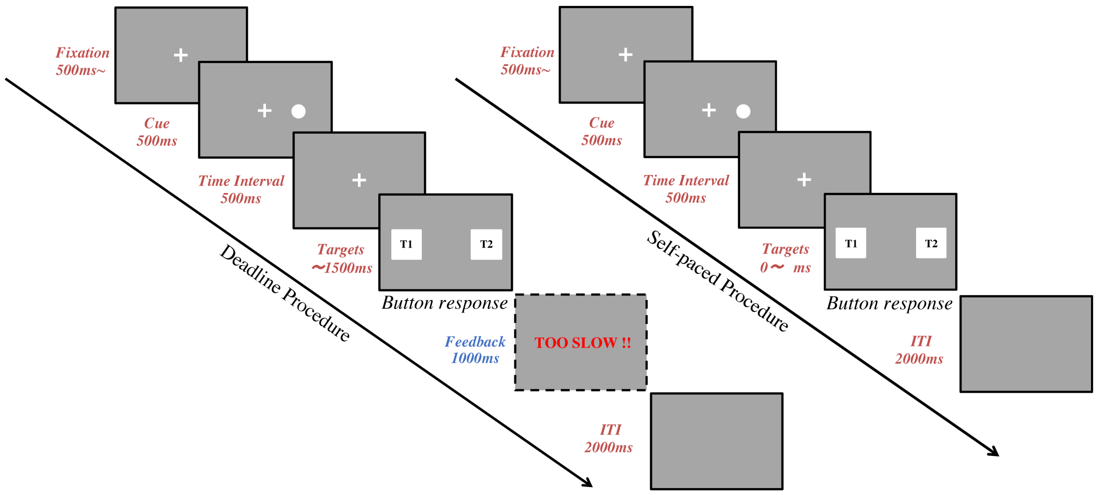

Figure 2. 2 Task procedure. The flow chart represents a trial sequence in the deadline experiments (left) and the self-paced experiments (right). Following fixation, a spatial cue was shown for 500 ms. Then, there was a 500 ms time interval. Finally, two target images were presented, one on the left and one on the right side of the screen, until the subject pressed a response button. In deadline experiments, a feedback screen was shown for 1,000 ms after the target images if the subject failed to give an answer within 1,500 ms. In all experiments, the inter-trial interval (ITI) was 2,000 ms.

Result

In the deadline experiments, all trials in which subjects failed to give a button-press response within 1.5 s were excluded from the analysis. For this reason, there was a total of 1.5% of all trials rejected for both behavioral and gaze analysis in the Deadline Face-cueing experiment, and 1.6% in the Deadline Food-cueing experiment. In addition, Bonferroni correction was used to set the alpha level at 0.05 for the entire data set in each experiment, in all statistical analyses.

Manual response analysis

Probability of choice

The probability of choosing the uncued target was calculated in all trials for each type of cue, by dividing the number of trials in which the uncued image was chosen by the total number of trials. This index ranged from 0 to 1; the higher, the more choices for uncued images, in line with the hypothesis of inhibition of return. To test whether there was a significant bias in the target choice, for each type of cue we compared the probability of choosing the uncued target against the chance level (0.5) by a two-tailed one-sample t-test.

Deadline Face-cueing experiment (DLFC)

In the DLFC (A panel of **Figure 2.3**), we found a significant choice bias following the disgusted face pre-cue (M_{DIS} = 0.573, 95% CI = [0.538, 0.607], t(27) = 4.087, *p* < 0.001, Cohen's *d* = 0.773). This result indicated a higher choice probability of uncued images, under urgency, when the cue is a disgusted face. There were no significant choice biases following the other pre-cues: dot (M_{DOT} = 0.526, 95% CI = [0.483, 0.567], t(27) = 1.216, p = 0.234, Cohen's *d* = 0.230); happy face (M_{HAP} = 0.526, 95% CI = [0.486,0.566], t(27) = 1.294, p = 0.207, Cohen's *d* = 0.245); and neutral face (M_{NEU} = 0.553, 95% CI = [0.513, 0.593], t(27) = 2.613, p = 0.014, Cohen's *d* = 0.494).

Self-paced Face-cueing experiment (SPFC)

In the SPFC (B panel of **Figure 2.3**), no significant choices biases were obtained for any of the pre-cues: dot (M_{DOT} = 0.505, 95% CI = [0.475, 0.536], t(27) = 0.342, p = 0.735, Cohen's *d* = 0.065); happy face (M_{HAP} = 0.515, 95% CI = [0.481, 0.550], t(27) = 0.862, p = 0.396, Cohen's *d* = 0.163); neutral face (M_{NEU} = 0.496, 95% CI = [0.453, 0.538], t(27) = -0.207, p = 0.837, Cohen's *d* = -0.039); disgusted face (M_{DIS} = 0.490, 95% CI = [0.464, 0.516], t(27) = -0.744, p = 0.463, Cohen's *d* = -0.141).

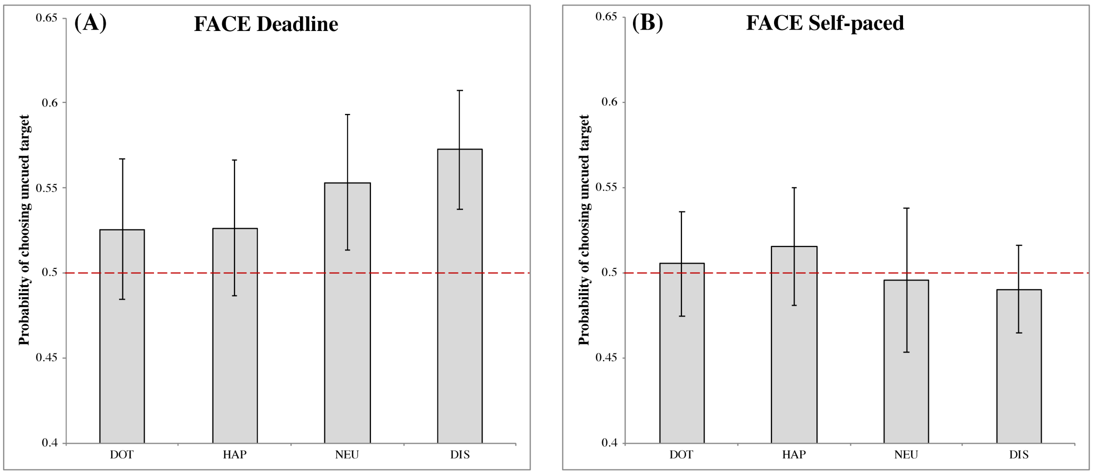

Figure 2. 3 The probability of choosing the uncued target in the face-cueing experiments. (A) and (B) represent the results of the deadline and the self-paced experiment respectively. Both panels show the data for different types of cue: dot (DOT), happy face (HAP), neutral face (NEU) and disgusted face (DIS). The red dashed line is the chance level (0.5) of selection. The error bars represent the 95% confidence interval around the mean in each condition.

Deadline Food-cueing experiment (DLFD)

In the DLFD (A panel of **Figure 2.4**), there was a significant choice bias following aversive food pre-cues (M_{AVE} = 0.555, 95% CI = [0.518, 0.592], $t(31) = 2.903$, $p < 0.01$, Cohen's d = 0.513). This result indicated a higher choice probability of uncued images, under urgency, when the cue is a disgusting food image. There were no significant choice biases following the other pre-cues: dot (M_{DOT} = 0.515, 95% CI = [0.493, 0.538], $t(31) = 1.340$, $p = 0.190$, Cohen's d = 0.237); and appetitive food (M_{APP} = 0.497, 95% CI = [0.468, 0.525], $t(31) = -0.241$, $p = 0.811$, Cohen's d = -0.043).

Self-paced Food-cueing experiment (SPFD)

In the SPFD (B panel of **Figure 2.4**), no significant choices biases were obtained for any of the pre-cues: dot (M_{DOT} = 0.520, 95% CI = [0.498, 0.542], $t(31) = 1.749$, p = 0.090, Cohen's d = 0.309); appetitive food (M_{APP} = 0.527, 95% CI = [0.503, 0.550], $t(31) = 2.247$, $p = 0.032$, Cohen's d = 0.397); and aversive food (M_{AVE} = 0.519, 95% CI = [0.494, 0.545], $t(31) = 1.466$, $p = 0.153$, Cohen's d = 0.259). Note that, for appetitive food, the Bonferroni correction produced a non-significant result, although in this case the target value of 0.5 was just outside the 95% CI.

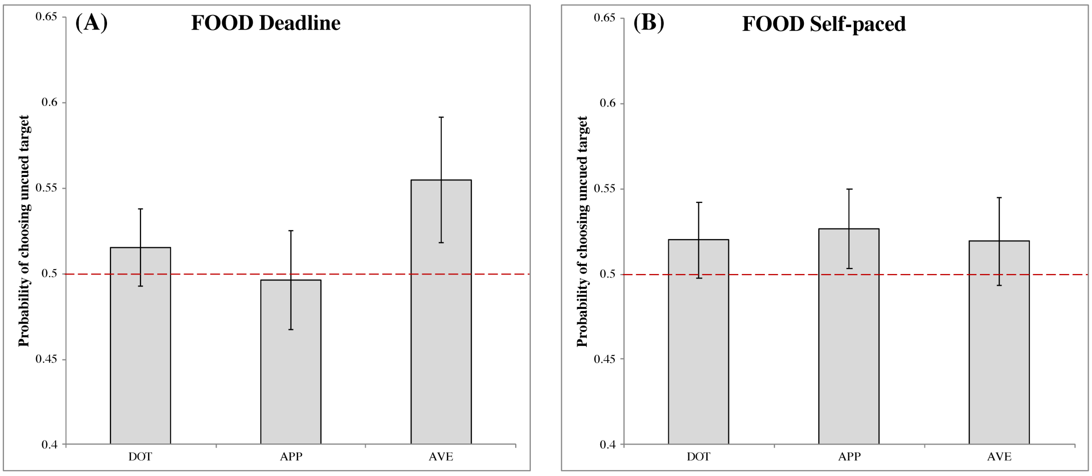

Figure 2. 4 The probability of choosing the uncued target in the food-cueing experiments. (A) and (B) represent the results of the deadline and the self-paced experiment respectively. Both panels show the data for different types of cue: dot (DOT), appetitive food images (APP), and aversive food images (AVE). The red dashed line is the chance level (0.5) of selection. The error bars represent the 95% confidence interval around the mean in each condition.

Response time

The response time (RT) was measured from the onset of the target screen until the button was pressed by the subject. The results are reported as averages from all trials as a function of the choice, either for a cued image ("Cued") or for an uncued image ("Uncued"). To investigate if the RT changed across different conditions, we conducted a two-way repeated measures ANOVA with the within-subjects factors cue type and choice type.

Deadline Face-cueing experiment (DLFC)

In the DLFC (A panel of **Figure 2.5**), there was a significant main effect of choice (cued versus uncued), $F(1, 27) = 7.808$, $MSE = 0.005$, $p < 0.01$, $\eta p^2 = 0.224$. However, there was no influence of the cue type, $F(3, 81) = 0.587$, $MSE = 0.001$, $p = 0.625$, $\eta p^2 = 0.021$; nor was there an interaction between choice and cue type, $F(3, 81) = 2.085$, $MSE = 0.002$, $p = 0.109$, $\eta p^2 = 0.072$. Compared with the mean of RT for choosing cued images ($M_{CUED} = 0.835$, 95% CI = [0.782, 0.887]), the RT for choosing uncued images was faster ($M_{UNCUED} = 0.807$, 95% CI = [0.753, 0.861]).

Self-paced Face-cueing experiment (SPFC)

In the SPFC (B panel of **Figure 2.5**), there was no significant effect of the type of choice, $F(1, 27) = 0.523$, MSE = 0.025, $p = 0.476$, $\eta p^2 = 0.019$, nor of the type of cue, $F(3, 81) = 0.422$, MSE = 0.013, $p = 0.738$, $\eta p^2 = 0.015$. There was also no interaction between choice and cue, $F(3, 81) = 0.564$, MSE = 0.024, $p = 0.640$, $\eta p^2 = 0.020$. The grand average of all RTs was 1.327 s (95% CI = [1.175, 1.480]).

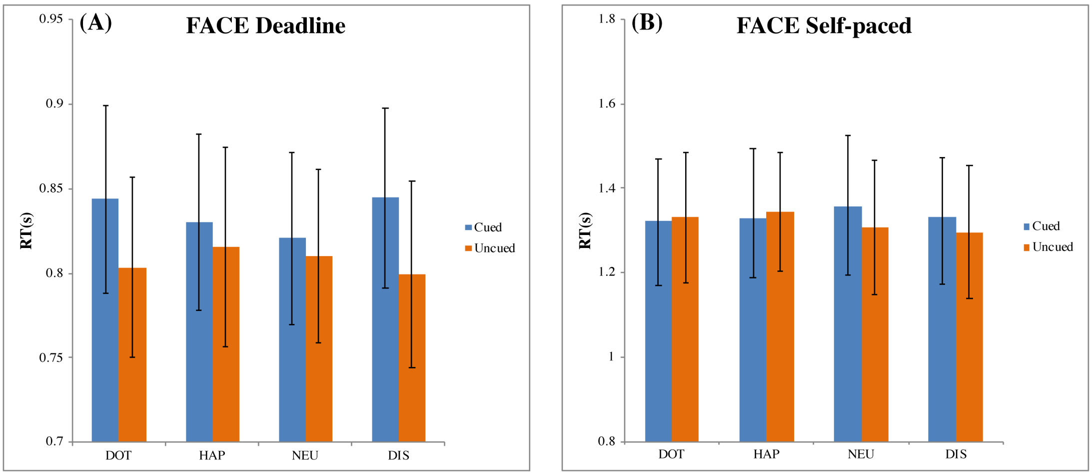

Figure 2. 5 Mean response time and standard errors in the face-cueing experiments. (A) and (B) represent the results of the deadline and the self-paced experiment respectively. Both panels show the data for different types of cue: dot (DOT), happy face (HAP), neutral face (NEU) and disgusted face (DIS). For each type of cue, the blue bars pertain to the response times when choosing cued targets (Cued); the orange bars pertain to the response times when choosing uncued targets (Uncued). The error bars represent the 95% confidence interval around the mean in each condition.

Deadline Food-cueing experiment (DLFD)

In the DLFD (A panel of **Figure 2.6**), we obtained a significant main effect of the type of choice on RT, F(1, 31) = 18.772, MSE = 0.002 , $p < 0.001$, $\eta p^2 = 0.377$. There was no influence from the cue type on RT, F(1.472, 45.625) = 0.351, MSE = 0.002 , $p = 0.640$, $\eta p^2 = 0.011$; nor was there an interaction between choice and cue, F(2, 62) = 2.221, MSE = 0.001 , $p = 0.117$, $\eta p^2 = 0.067$. Compared with the mean RT for choosing the cued image (M_{CUED} = 0.893, 95% CI = [0.851, 0.935]), the mean RT for choosing the uncued image was faster (M_{UNCUED} = 0.866, 95% CI = [0.820, 0.913]).

Self-paced Food-cueing experiment (SPFD)

In the SPFD (B panel of **Figure 2.6**), there was no significant effect of choice, F(1, 31) = 1.938, MSE = 0.020, $p = 0.174$, $\eta p^2 = 0.059$, nor of the cue type, F(2, 62) = 3.235, MSE = 0.020 , $p = 0.054$, $\eta p^2 = 0.090$. There was also no interaction between choice and cue type, F(2, 62) = 0.651, MSE = 0.015 , $p = 0.525$, $\eta p^2 = 0.021$. The grand average of all RTs was 1.655 s (95% CI = [1.387, 1.924]).

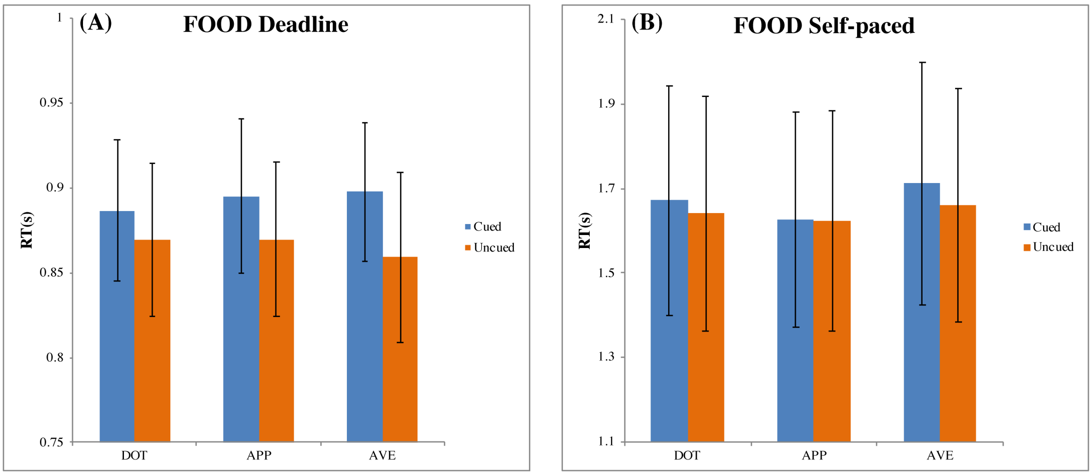

Figure 2. 6 Mean response time and standard errors in the food-cueing experiments. (A) and (B) represent the results of the deadline and the self-paced experiment respectively. Both panels show the data for different types of cue: dot (DOT), appetitive food images (APP), and aversive food images (AVE). For each type of cue, the blue bars pertain to the response times when choosing cued targets (Cued); the orange bars pertain to the response times when choosing uncued targets (Uncued). The error bars represent the 95% confidence interval around the mean in each condition.

Gaze analysis

For the gaze analysis, we followed the same procedure as in previous studies (Shimojo et al., 2003; Zommara et al., 2018) to plot the gaze distribution. In order to know where the subject's gaze was located and how the gaze distribution changed, we conducted the analysis with two areas of interest: the left and right hemi-fields (i.e., half screen). We assigned a value of '1' if the subject's gaze was directed to the same side of the cue; a value of '0' if the gaze was on the other side; and 'not-a-number (NA)' if the gaze was outside of the screen. All gaze sampling points, from the onset of the pre-cue until the average response time in each experiment, were calculated to obtain the likelihood of looking at the cueing side, by averaging across all trials and subjects. Based on this analysis method, if the likelihood value is higher than '0.5', it means there is a gaze bias toward the cueing side.

The gaze patterns were determined by the type of experiment (DLFC, SPFC, DLFD, and SPFD) and the ensuing choice (Cued versus Uncued), but there were no significant main effects or interactions with the affective value of the pre-cue. As presented in **Figures 2.7** and **Figure 2.8** (collapsed across types of pre-cue), the gaze curve showed similar patterns across all experiments. In all cases, the gaze likelihood at the onset of the pre-cue was at chance level (0.5), and then tended to shift toward the cueing side, peaking to a probability of around 0.7 for face images, and around 0.8 for food images. In order to establish the exact time of gaze shifting to the cueing side, we sub-divided the time into 20 bins of 50 ms (i.e., the time duration of cue and time interval). Two-tailed one-sample t-tests against 0.5 (for each bin, with Bonferroni correction) revealed a significant gaze bias, starting at 350 ms for choosing the cued image in DLFC, $p < 0.001$, starting at 300 ms for choosing the uncued image in DLFC, $p < 0.001$; and at 300 ms for both types of choice in SPFC, $p < 0.001$ (**Figure 2.7**). In the Food-cueing experiments, the gaze bias started at 300 ms for both choice conditions in DLFD, $p < 0.001$; and at 300 ms for choosing the cued image in SPFD, $p < 0.001$, versus at 250 ms for choosing the uncued image in SPFD, $p < 0.001$ (**Figure 2.8**). In all cases, the gaze bias toward the cueing side ended, returning to chance level or even dipping below chance level, before the onset of the target screen.

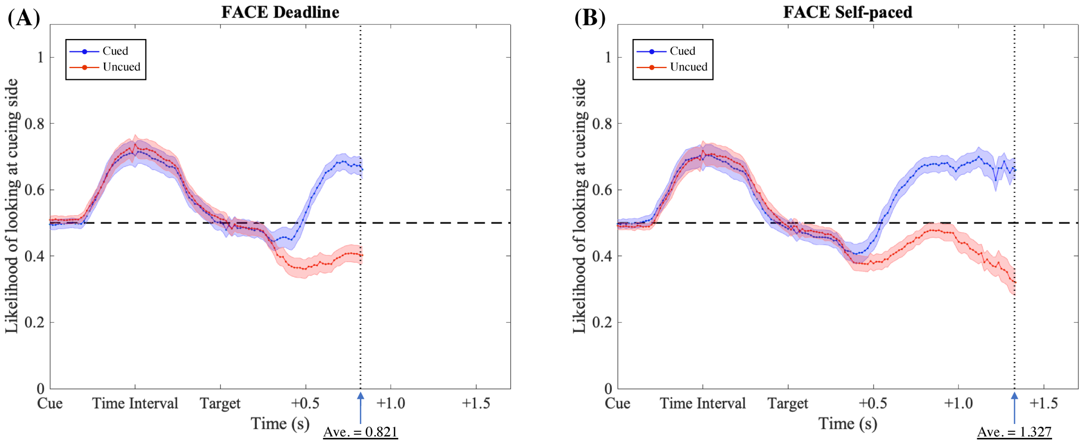

Figure 2. 7 Gaze likelihood analysis of the face-cueing experiments. (A) and (B) represent the result of the deadline and the self-paced experiment respectively. The likelihood that a subject's gaze was directed toward the cueing side is plotted against the time past from the onset of the cue until the average response time. The black dashed lines reflect the chance level (0.5) of likelihood. The blue dotted lines represent the data when choosing the cued target (Cued); the red dotted lines represent the data when choosing the uncued target (Uncued). The shaded areas represent the range of the standard error of the mean for each plot.

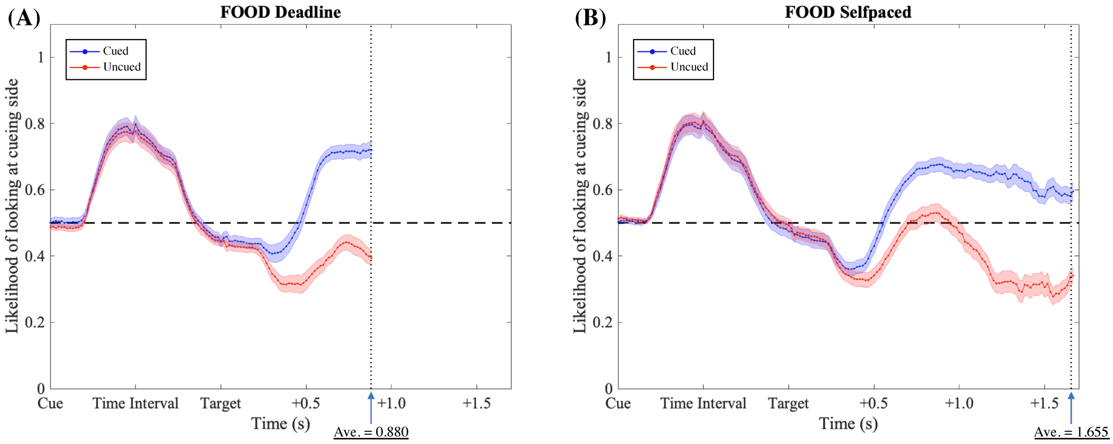

Figure 2. 8 Gaze likelihood analysis of food-cueing experiments. (A) and (B) represent the result of the deadline and the self-paced experiment respectively. The likelihood that a subject's gaze was directed toward the cueing side is plotted against the time past from the onset of the cue until the average response time. The black dashed lines reflect the chance level (0.5) of likelihood. The blue dotted lines represent the data when choosing the cued target (Cued); the red dotted lines represent the data when choosing the uncued target (Uncued). The shaded areas represent the range of the standard error of the mean for each plot.

Next, we investigated the differences between the two types of choice (cued vs. uncued), by focusing on the data from the onset of the target screen. We sub-divided the time into 30 bins of 50 ms (i.e., 1.5 s from the onset of target screen). Paired-sample t-tests (for each bin, with Bonferroni correction) were performed comparing between the cued choices and the uncued choices. The results revealed significant differences, starting from 550 ms in the Deadline Face-cueing experiment, $t(27) = 4.200$, $p < 0.001$, Cohen's $d = 0.794$; and from 600 ms in the Self-paced Face-cueing experiment, $t(27) = 3.846$, $p < 0.001$, Cohen's $d = 0.727$ (**Figure 2.7**). Significant differences were obtained starting from 450 ms in the Deadline Food-cueing experiment, $t(31) = 3.928$, $p < 0.001$, Cohen's $d = 0.694$; and from 550 ms in the Self-paced Food-cueing experiment, $t(31) = 4.547$, $p < 0.001$, Cohen's $d = 0.804$ (**Figure 2.8**). In all cases, the divergences reflected gaze biases toward the side of the ensuing choice.

Finally, in order to further investigate the start of the decision phase, we focused on the negative peak (i.e., lowest value below 0.5 in a 50 ms bin) in the data for the Cued choices at a time when the gaze curves between Cued and Uncued choices were not significantly different (i.e., before the divergence of the decision process, as determined above). From the hypothesis of inhibition of return, we should expect this value to be significantly lower than 0.5. In line with accumulator models of preference formation, this would reflect a starting point bias toward the Uncued location in the decision process. For each of the four experiments, we therefore performed a two-tailed one-sample t-test against 0.5 for the pre-divergence negative peak in the Cued choices.

In the Deadline Face-cueing experiment, the pre-divergence negative peak in the Cued choices was reached at 350 ms after Target onset (0.447). At this time there was no significant gaze bias in the direction of the Uncued location, $t(27) = -1.905$, $p = 0.068$, Cohen's $d = -0.360$. In the Self-paced Face-cueing experiment, the peak was reached at 450 ms after Target onset (0.409). At this time there was a significant gaze bias in the direction of the Uncued location, $t(27) = -3.115$, $p < 0.01$, Cohen's $d = -0.589$. Similar gaze biases in the direction of the Uncued location were obtained in the Deadline Food-cueing experiment, with a pre-divergence negative peak at 350 ms after Target onset (0.409), $t(31) = -3.398$, $p < 0.005$, Cohen's $d = -0.601$; and in the Self-paced Food-cueing experiment, peaking at 400 ms (0.361), $t(31) = -6.886$, $p < 0.001$, Cohen's $d = -1.217$.

Discussion

The principal aim of this study was to elucidate the role of visual attention in the evaluative processing. To this end, we conducted four experiments to examine pre-cueing effects in a choice task based on perceived attractiveness. In our experimental paradigm, we varied both the type of cue (face versus food images, with different affective associations) and the time constraints (1.5 s deadline versus self-paced). The task for subjects was to choose the more preferred picture from a pair of abstract art images. We measured the choice probabilities, the response times, and the gaze patterns. Across the experiments we found a highly consistent pattern of results, with clear cueing effects on all three measures. First, with respect to the choice probabilities, there were significant influences from pre-cues with negative associations, but only under urgency. In deadline experiments, subjects tended to choose the uncued target, both following a disgusted face and following an aversive food image. No other choice biases were obtained. Second, with respect to the response times, choices for uncued targets tended to be faster than choices for cued targets, but only under urgency. Again, this pattern was consistent across experiments, both for face cues and for food cues. Finally, with respect to gaze likelihood, in all experiments, the pre-cues elicited a clear gaze bias to the cueing side, which subsequently dissipated before the onset of the target screen and further tended to develop into a bias in the opposite direction, in line with the phenomenon of inhibition of return. From a starting point biased to the uncued location, the gaze patterns then diverged in the direction of the ensuing choice.

Taken together, the data supported the information-integration hypothesis, but not the gradual-commitment hypothesis. The affective value of the pre-cue had a decisive impact on the subsequent choice under urgency, indicating that the information was integrated in the preference formation. The gaze data and manual response times further suggested that the pre-cues had been effective, in agreement with the phenomenon of inhibition of return. The cues elicited a biphasic gaze bias in opposite directions, first to the cued location and then to the opposite direction. Under urgency, the manual responses were faster for uncued targets than for cued targets.

Cueing effects on preference formation

In both deadline experiments, DLFC and DLFD, the results of negative cues (i.e., disgusted face and aversive food) indicated that the probability of choosing the uncued target was significantly greater than chance (0.573 in DLFC; 0.555 in DLFD). No significant difference was found when using other cues (i.e., neutral and positive cues). Additionally, the results in both deadline experiments showed that the response time when choosing uncued targets was faster than that when choosing cued targets.

The most plausible explanation, in line with a vast amount of research on covert visual attention, is that the pre-cues attracted not only overt attention, as evidenced by the gaze biases, but also covert attention, setting in motion the mechanisms that underlie inhibition of return (engagement, disengagement, shift). This can explain why uncued targets were chosen faster than cued targets, regardless of the type of cue, in deadline experiments. Conversely, the fact that there were no response-time differences in the self-paced experiments suggests a short-lived influence of inhibition of return. Such influence dissipated when subjects took more time to reflect on their preferred choice.

Although the attentional processes were activated by all pre-cues, the nature of the influence changed depending on the affective value of the pre-cue. Neutral cues in all experiments failed to influence the direction of the subsequent choice. In this sense, it appears that the phenomenon of inhibition of return by itself does not suffice to influence the actual process of preference formation. Similarly, positive cues (happy face or appetitive food) had no measurable impact on the direction of choice. However, the clear choice bias following negative cues under urgency indicated that the affective value interacted with the attentional processing. Effectively, the value of the cued position had decreased, and thus impeded the selection of the target image that appeared there. We suggest that the negative affective value promoted attentional disengagement, leading to a pronounced bias against the same position. In other words, the negative value was integrated in the preference formation in such a way as to favor the alternate choice. At a more general level, this finding is consistent with a host of studies on the valence-dependent impact of emotion on attention (e.g., Tomkins, 1970; Toda, 1980; Lerner et al., 2014).

It should be noted that the preference formation here reflects a coalescence of object evaluation and manual choice behavior. In the present experiments, subjects were always required to select their preferred object. Consequently, we cannot establish whether the influence of affective cues under urgency are due to an actual increase in the evaluation of the chosen objects, or a more general preference to press a button opposite cues with negative associations. The critical test to disambiguate these possibilities would be to require subjects to pick the less preferred object. If, in such a test, the manual choice pattern switches, the influence of negative cues under urgency must pertain to the actual evaluation of the objects. Conversely, if the manual choice pattern stays the same, the effects would be due to response association at the level of manual motor control.

Interestingly, a study on consequences of attentional inhibition during visual search suggested that the spatial control of attention may have an impact on the actual evaluation of objects (Raymond et al. 2005). The paradigm consisted of search trials followed by evaluation trials. During search trials, subjects were required to locate colored patterns or tinted faces. In subsequent evaluation trials, subjects were required to evaluate objects that had been either distractors or targets in the search trials. Distractors were rated lower than targets, and this effect was more pronounced when the distractors had been near the targets during the search trials. The effect of target-distractor proximity was observed even when the objects were presented at different locations in the evaluation trials. Overall, the data suggested that location-based suppression translated into emotional devaluation. Future work can build on this paradigm, as well as ours in the present study, to examine the exact nature of the influences of attentional control on preference formation.

The role of urgency

By comparing the results of deadline experiments and self-paced experiments, we aimed to elucidate the impact of urgency, both on evaluative decision-making as a whole, and specifically on the pattern of cueing effects. To be sure, our results confirmed that, compared with self-paced experiments, deadline experiments yielded much faster response times (an overall difference of more than 500 ms in face-cue experiments, and more than 700 ms in food-cue experiments). The gaze-likelihood analyses also showed earlier divergence toward the preferred side in deadline experiments as compared to self-paced experiments. Importantly, in self-paced experiments we found no significant effects at all from pre-cues on the manual responses. When subjects were free to take as much time as they wanted, there were traces of inhibition of return in the gaze patterns, with gaze biases that clearly showed a biphasic process of moving toward, and then away from, the cued location, but this did not translate into affective influences in the response times and choice probabilities. In terms of accumulator models (Krajbich et al., 2010; Gluth et al., 2018; 2020), the results imply that the pre-cues produced a bias in the starting position of the evidence accumulation, but, with respect to preference formation, the pre-cues mattered only under urgency.

Urgency effectively changes the threshold for decision-making (Reddi and Carpenter, 2000; Noorani, 2014; Noorani and Carpenter, 2016). When given less time for choosing, people must take shortcuts in the decision-making process. Reddi and Carpenter (2000), adopting the LATER model for decision-making (Carpenter, 1981), pointed out that the accelerative effect of urgency is mainly attributable to its influence on the threshold at which a response is initiated, not the efficiency of information processing. Subjects would lower their decision threshold under urgency, while still extracting information as efficiently as they can. This implies that pre-existing response biases have an exacerbated effect under urgency. Accordingly, with response time shortened and the efficiency of information processing unvaried, it is reasonable to assume that, in the present study, subjects acquired less information from the targets in the deadline experiments than in the self-paced experiments. We suspect that the gap in the amount of information available to the subjects in deadline versus self-paced experiments may explain why the cues were effective only under urgency. The cueing, as one form of information, became relatively more significant as the total amount of information decreased, and could therefore have a greater impact on the evaluative decision-making under urgency. In other words, the cueing effects may be enhanced when less information is available to the subjects, and weakened otherwise.

Additive versus multiplicative role of attention in preference formation

In previous studies, the gaze cascade phenomenon has been demonstrated multiple times with a range of variations, including both preferential tasks (Shimojo et al., 2003; Simion & Shimojo, 2006, 2007; Bird et al., 2012) and non-preferential tasks

(Glaholt and Reingold, 2009; Nittono and Wada, 2009; Schotter et al., 2010; Morii and Sakagami, 2015; Zommara et al., 2018). Shimojo et al. (2003) interpreted the phenomenon as an active positive influence from the gaze on preference formation (i.e., the gradual-commitment hypothesis). Phrased in terms of accumulator models (Krajbich et al., 2010; Gluth et al., 2018; 2020), the gradual-commitment hypothesis implies that gaze duration leads to a positive additive effect on preference formation. In the present study, we obtained significant gaze biases toward the ensuing choices in all conditions. However, the present cueing effects under urgency appear in conflict with the notion of an positive additive effect from the gaze on preference formation. Despite the fact that the gaze tended to go to the pre-cues in all conditions, this did not lead to any advantage in the preference formation for the cueing side. Moreover, the negative influences from the face cue with an expression of disgust and from aversive-food cues cannot easily be reconciled with the notion that viewing leads to liking.

Instead, we propose that the gaze, as a form of overt attention, can overlap with covert attention to show inhibition of return and to perform a function of information integration. The integrated information can either promote or impede preference formation depending on its valence. In terms of accumulator models of preference formation, the information-integration hypothesis appears consistent with a multiplicative role of attention, as often touted in neurophysiological investigations of attention (e.g., Stoppel et al., 2011; Lee et al., 2016). Multiplicative gain modulation by attention might explain how gazing at negatively valued objects leads to further devaluation of the attended objects. Nevertheless, we cannot rule out a form of scaling that leads to subtraction of value through additive inhibitory mechanisms (Ayaz and Chance, 2009), or more complex forms of information integration with sequential stages of multiplicative, and then additive or subtractive, scaling (Andersen et al., 2012). While it may be difficult to actually model the influence of attention on preference formation in the present paradigm, it seems appropriate at least to rule out the notion of "Pavlovian approach." There is not necessarily a positive additive effect from attention on preference formation.

This interpretation mirrors other findings in our own laboratory, undercutting the notion that viewing leads to liking. Using an absolute-evaluation paradigm with food images, we found that in most situations, viewing time was not associated with increased preference formation when subjects evaluated food images one at a time, rather than making choices between pairs of images (Wolf et al., 2018, 2019). The entire pattern of data suggested that increased viewing times occurred under indecision or deliberative processing, that is, when subjects engaged in a prolonged effort of information integration. Conversely, the phenomenon of the gaze cascade may depend on the decision goal (Van der Laan et al., 2015), particularly in situations where the gaze can act as a spatial precursor to choice (Gerbella et al., 2017). In other words, the gaze would not have a direct positive impact on preference formation at all, but might perform a role in guiding motor behavior toward a spatial choice. The latter function would create the impression that viewing leads to liking in situations where liking is expressed as a spatial choice.

General Discussion

The current project worked on illustrating the relationship between visual attention and preference formation. To this end, a behavioral experiment which applied spatial-cueing paradigm with preferential task was carried out. The result revealed a diverse cueing effect on “liking” choice (i.e., Part 1). Based on the pilot study in Part 1, we performed an eye-tracking experiment with a tightly controlled setting to gain a clearer understanding on the interaction of gaze and preference in Part 2. Across the entire data sets, we found a very consistent pattern in results of both behavioral response (i.e., choice probability and response time) and eye data. Firstly, in terms of the manual response, our result revealed that the cue has an impact on preference, and the effect was varied depending on the nature of the cue. Secondly, the cueing effect on preference seemed to be minor if people had longer time to make their decisions. Taken together, it can be concluded that the “information” and the “time” are two crucial factors in preference formation. To be more specific, the cueing effect on preference is short-lived, and the information of the cue was integrated in the process of preference formation, thus it showed a strong bias towards the uncued choice with negative cues under urgency.

With regards to the time constraint of response, the result showed a much faster response time and a much stronger cueing effect in the deadline experiments, which has been discussed in detail in Part 2. In deadline experiments, the maximum duration for selecting was set as 1.5 s, the same as what previous study had used for investigating social preference in autism (Gharib et al., 2015). It is obvious that the timing of 1.5 s has also worked on preference well in current study, while the border remains unclear. Consequently, it is worth exploring the effect of different time constraint on decision-making, not only for a further understanding on the relationship of time and decision, but also for verifying the assumption which had pointed out the reason of different results between the deadline and the self-paced experiments are due to a gap in the amount of available information. If it is true, a shorter timing for selection would probably increase the cueing effect on decision.

In all experiments, subjects had been required to choose the more preferred picture basing on their personal preference. Even though the sense of liking is thought to be subjective, the judgment depends on that should be more than a result of internal selection. In other words, the external factors such as varied environment, or social elements probably work on preference together. Therefore, applying a cue in the preferential task has provided us an effective approach to demonstrate the influence of the external factors on preference. However, it should be noted that the liking choices which subjects had made in our experiment have its own property. In view of the paradigm we applied, it is difficult to declare that our result is a "real preference" of subject, rather than a result of the manipulation of cues or time. Accordingly, it is necessary to conduct a preferential task without applying any cue or time constraint if one wants to define the real preference. For instance, by presenting the same target stimuli multiple times in a random order, one can assess more accurately subjects' real preference based on what the subjects consistently choose. By comparing to the present result, one can gain a more accurate understanding on how the cue influences subjects' real preference.

The result of gaze analysis has indicated that gazing did not provide direct advantage to increase preference for the attended objects. Although the gaze was attracted by the pre-cues in all conditions, it did not lead a higher choice probability to the cued target. Similar to previous research (Gerbella et al., 2017), we argued that the viewing (or gazing) is not necessary to enhance the preference, but act as a spatial precursor to the choice. Besides, the "gaze cascade" phenomenon has been observed in all experiments, indicating a gaze bias towards the chosen side right before their decision. Previous studies have found the "gaze cascade" phenomenon in both preferential task and non-preferential task, which indicated the possibility of a more complex mechanism of looking behavior.

In other words, the gaze may not or may not only due to the preference, but because of some other factor, such as curiosity. It has been known that curiosity plays a role as intrinsic motivation to learn and acquire information, and it has multiple influences on both attention and eye movements (Gottlieb et al., 2013; Baranes et al., 2015). Thus, it could not be disambiguated that the mentioned results are accurate reflections of preference, rather than a reflection of curiosity.

There are several promising future works in the aspect of generalization. We have investigated the effect of affective cues on preference, in order to know whether the same methodology can be applied to other types of stimuli, it is worth attempting relevant studies. For instance, by replacing abstract images with food or face, future study can examine the cueing effect on the targets containing more features. In addition, since preference is not the only value-based decision-making, it would be very interesting to conduct experiments regarding other types of choice, namely, the moral decision-making. Instead of asking people their preference for objects, one can apply a set of moral images and give questions concerning their ethical attitude such as fairness, political view and so on.

Last but certainly not least, one could gain another important insight into the comprehension of the function of deadline by further analyzing the response time of self-paced experiment. Specifically, by dividing the response time into a faster (e.g., less than 1.5 s) and a slower group, one would be able to analyze the corresponding choice probability, and the cueing effect of the two groups. If the cueing effect we have found from deadline experiments is due to the speed of responses, then a similar trend of choice probability result should appear in the faster group. That is, a significant choice bias on uncued target associated with negative cues. However, if the pronounced cueing effect in deadline experiment was not due to the speed itself, but was an external pressure (i.e., forced to be fast), then the trend would not be found in neither faster nor slower group. To be more general, if the voluntary faster response can elicit the cueing effect, it would suggests that the effect we found in current study may be more effective to subjects who are "fast decision makers"; otherwise, it indicates that the cueing effect is more dependent on external environment.

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Appendices

Appendix 1: Choice rate divided into sessions

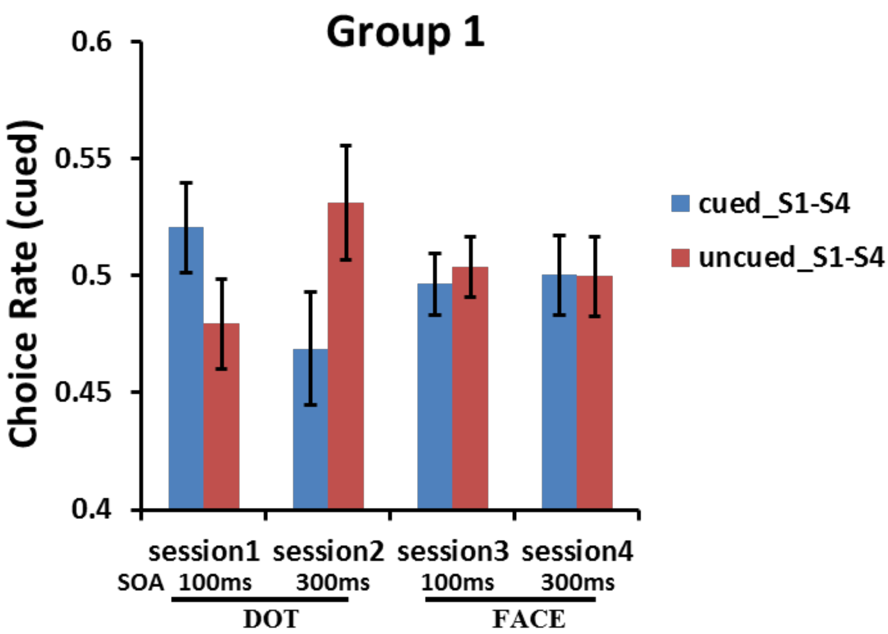


Figure A. Choice rate divided into sessions in Group 1. The order of the experiment in group 1 is from session 1 to session 4.

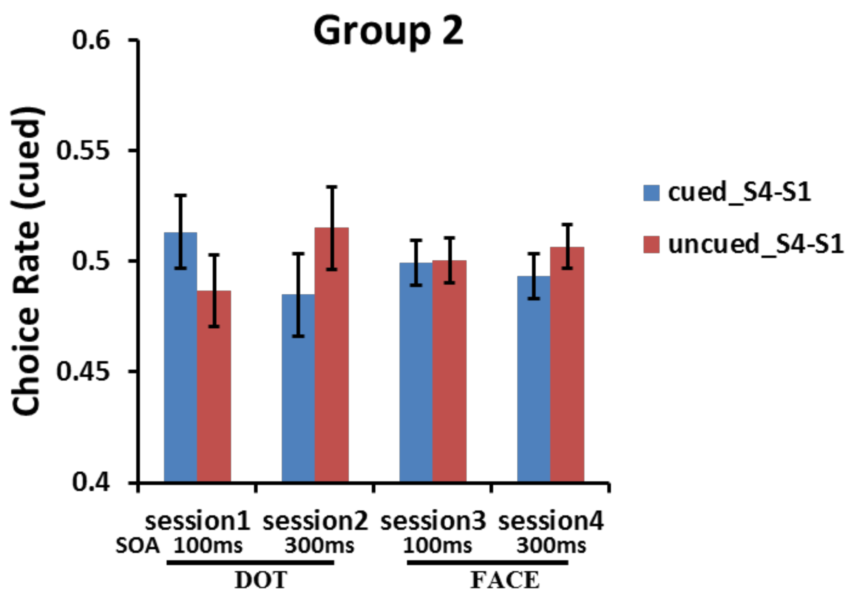
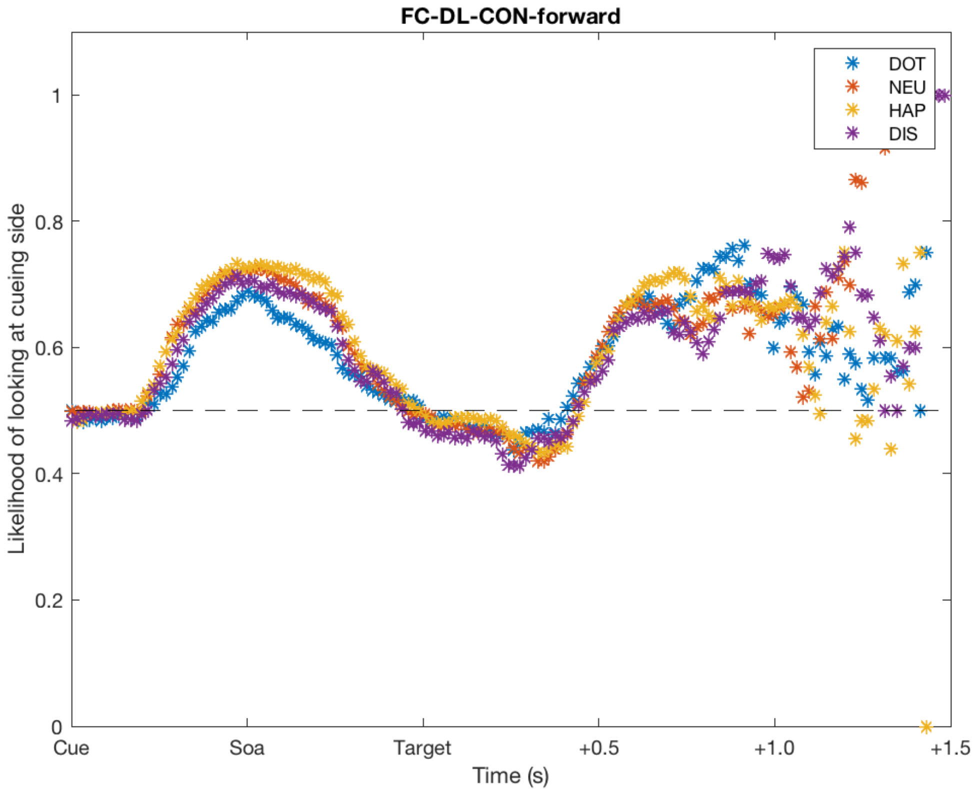
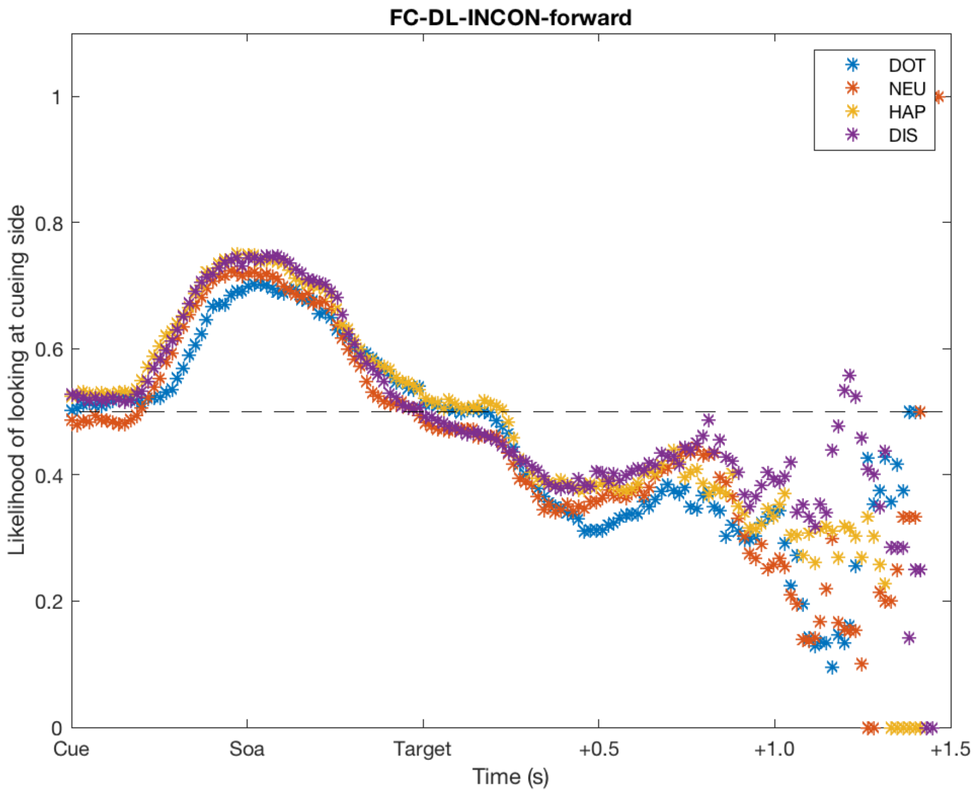
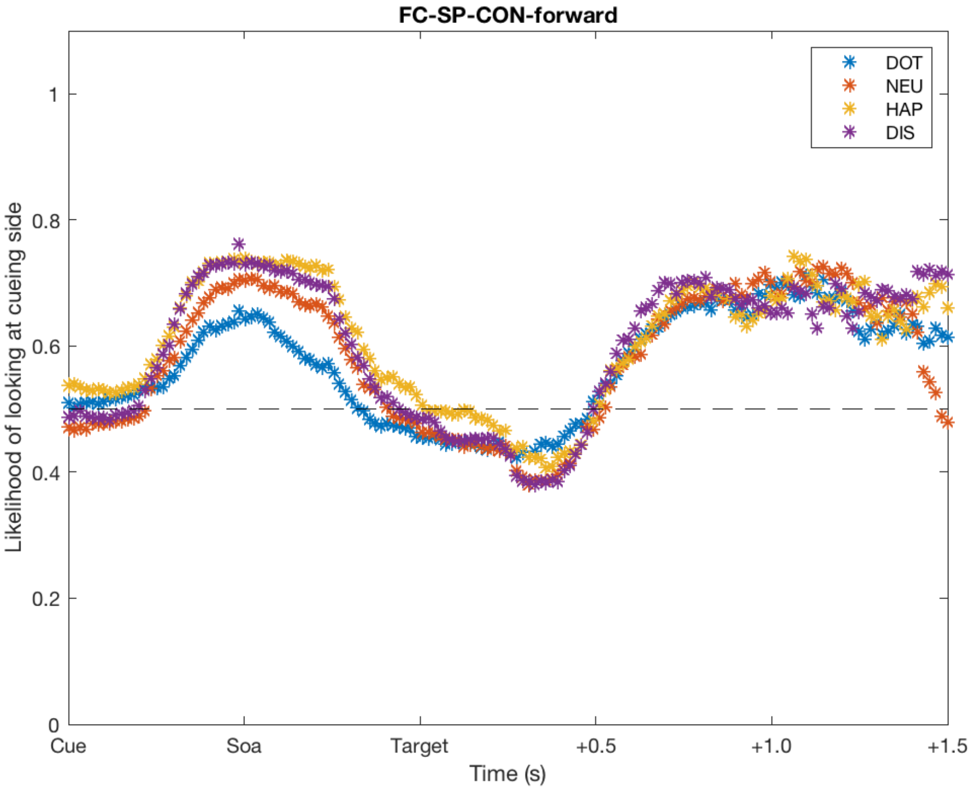


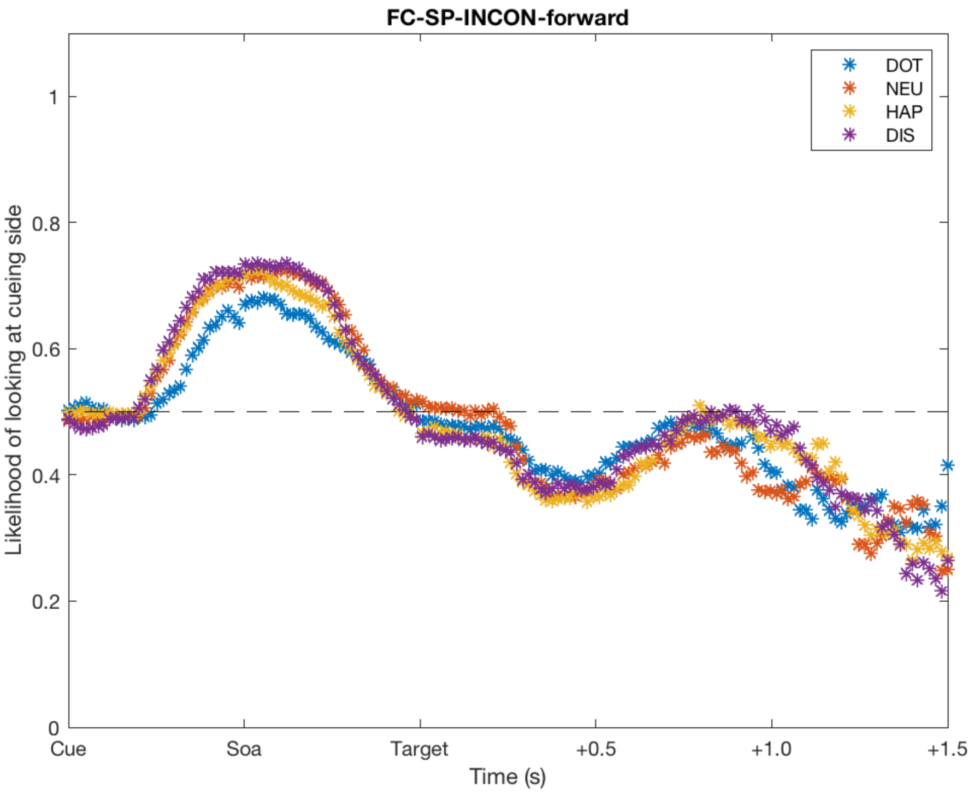
Figure B. Choice rate divided into sessions in Group 2. The order of the experiment in group 2 is from session 4 to session 1.

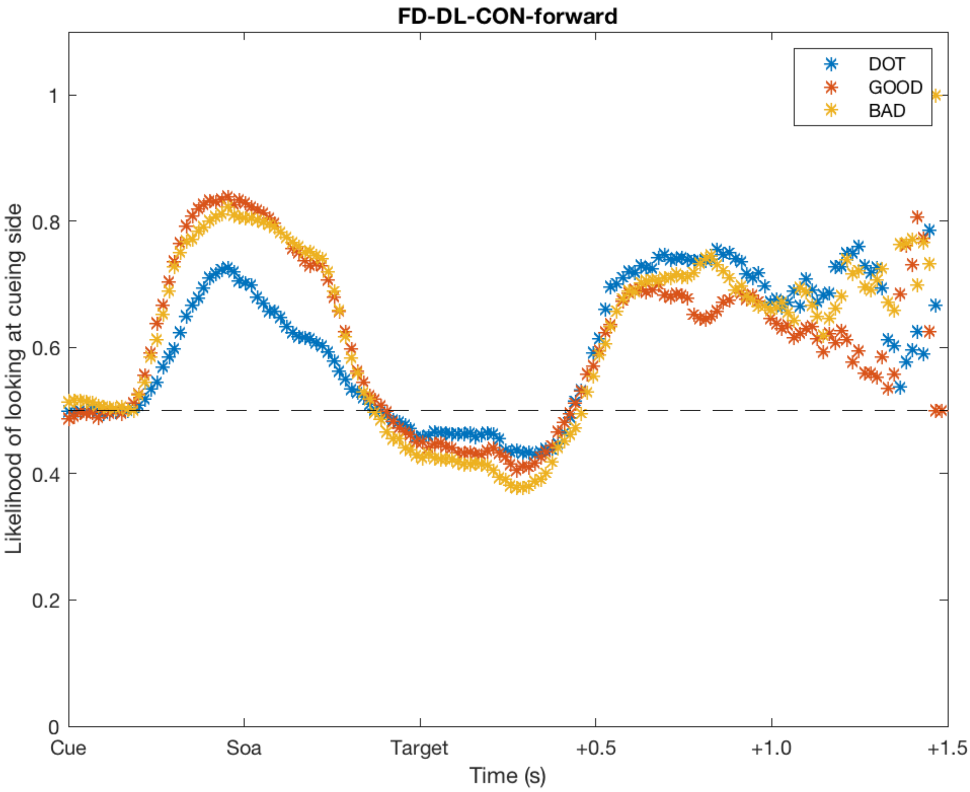
Appendix 2: Gaze pattern divided by different types of cue:

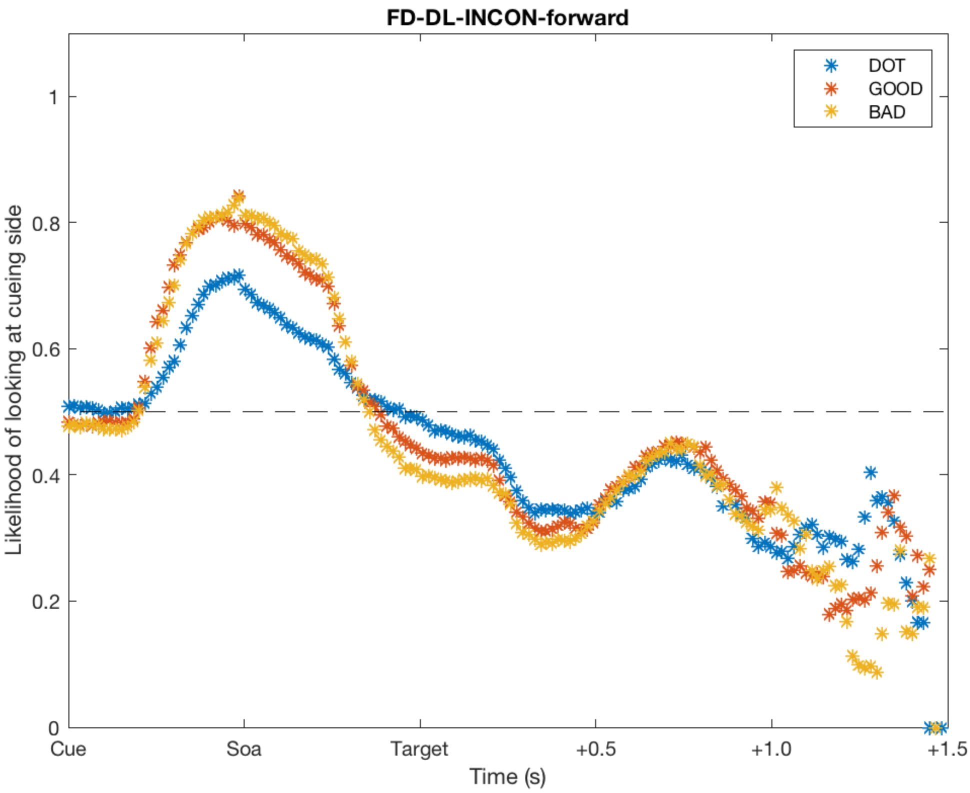

FC-DL-CON-forward
DOT
NEU
HAP
DIS
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)

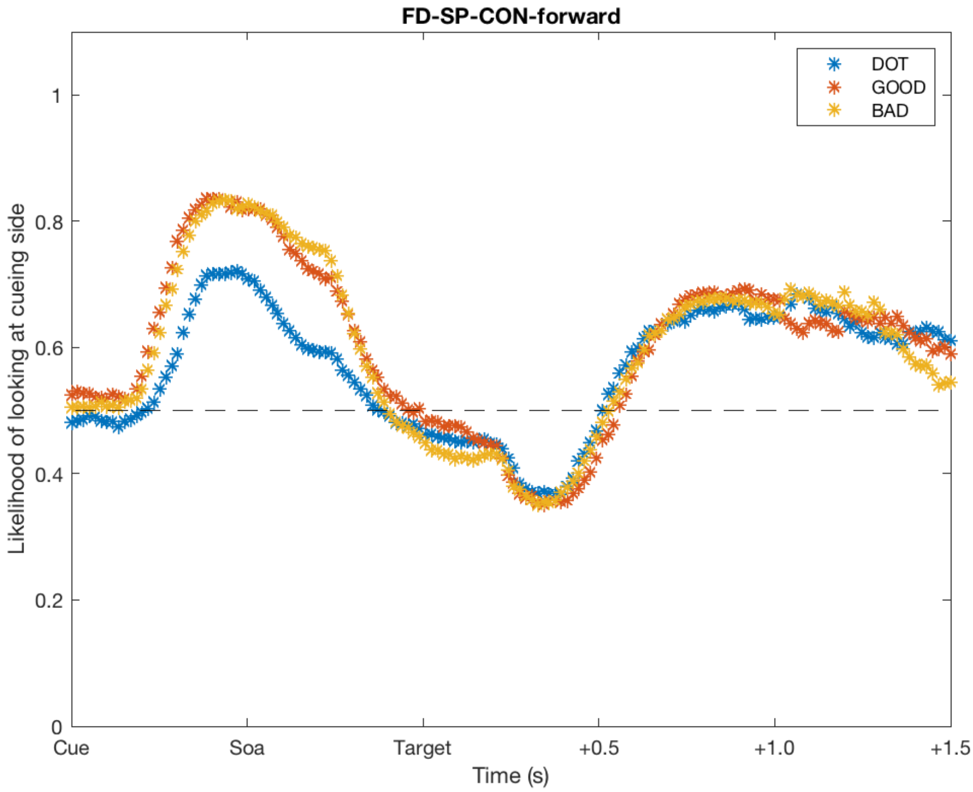

FC-DL-INCON-forward
DOT
NEU
HAP
DIS
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)

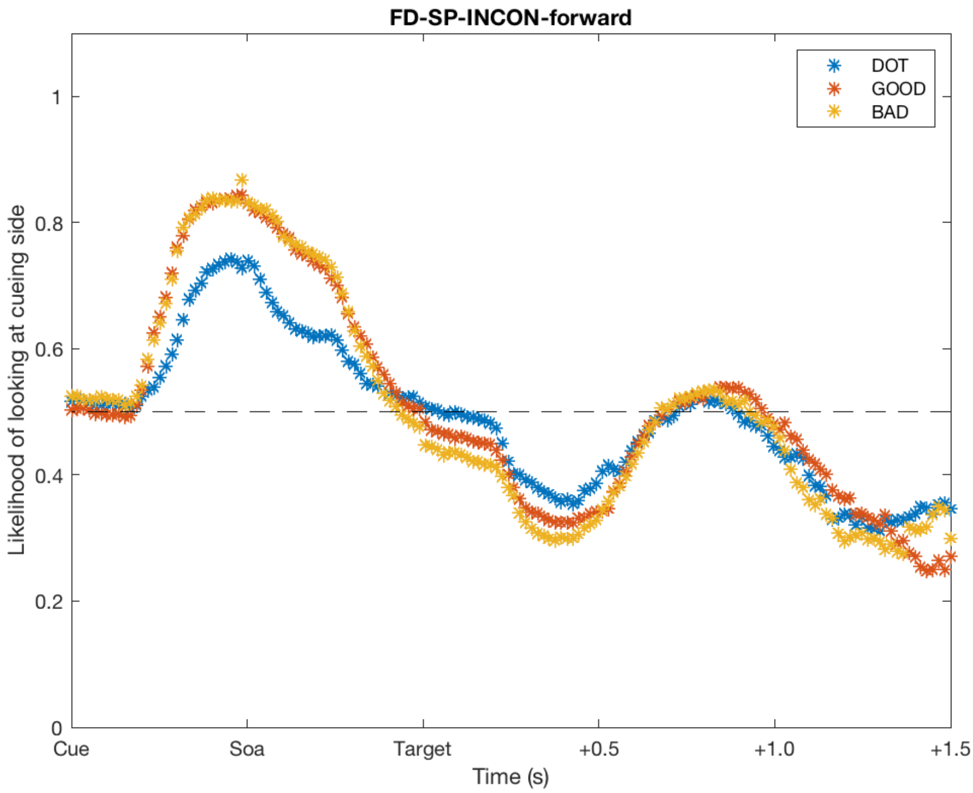

FC-SP-CON-forward
DOT
NEU
HAP
DIS
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)


FC-SP-INCON-forward
DOT
NEU
HAP
DIS
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)


FD-DL-CON-forward
DOT
GOOD
BAD
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)


FD-DL-INCON-forward
DOT
GOOD
BAD
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)


FD-SP-CON-forward
DOT
GOOD
BAD
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)


FD-SP-INCON-forward
DOT
GOOD
BAD
Likelihood of looking at cueing side
0
0.2
0.4
0.6
0.8
1
Cue
Soa
Target
+0.5
+1.0
+1.5
Time (s)