Emotional Effects on Visual Information Processing

FA4869-08-0004

AOARD 074018

Report

October 24, 2009

Yei-Yu Yeh

Department of Psychology
National Taiwan University

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
27 JAN 2010	**FInal**	**08-01-2008 to 08-10-2009**

4. TITLE AND SUBTITLE
Emotional Effects in Visual Information Processing

5a. CONTRACT NUMBER
FA48690810004

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Yei-Yu Yeh

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Taiwan University,No.1, Sec. 4, Roosevelt Rd.,Taipei 106,Taiwan,TW,106

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AOARD, UNIT 45002, APO, AP, 96337-5002

10. SPONSOR/MONITOR'S ACRONYM(S)
AOARD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AOARD-074018

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The objective of this research project was to investigate how emotion influences visual information processing and the neural correlates of the effects. Behavioral studies were proposed to address three issues. The first issue is related to the automaticity of processing task-irrelevant emotional features. The second issue is associated with the effect of positive affect on visual information processing and the third issue addresses the effect of capacity limitation on processing emotional information in a dynamic environment. The third issue was base on imaging experiments to understand the neural mechanisms of the impact of emotion on visual information processing. Progress is described.

15. SUBJECT TERMS
Visual Cognition

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**29**	

Aim

The objective of this research project is to investigate how emotion influences visual information processing and the neural correlates of the effects. Behavioral studies were proposed to address three issues. The first issue is related to the automaticity of processing task-irrelevant emotional features. The second issue is associated with the effect of positive affect on visual information processing and the third issue addresses the effect of capacity limitation on processing emotional information in a dynamic environment. On the basis of the results from the behavioral studies, we planned to conduct imaging experiments to understand the neural mechanisms of the impact of emotion on visual information processing. In all of the behavioral experiments, we used the same protocol as what was approved. The exact stimulus-task context differed depending on the issue addressed.

Progress

We completed the experiments related to the first issue and reported in the previous progress report. A revised manuscript is under review. In the previous progress report, we also described two failed pilot experiments related to the second issue; reported that a pilot experiment was undergoing to investigate the third issue. In this report, we describe what we have completed during the period since last submission of a progress report. No imaging experiment has been conducted, because none of the results clearly showed any benefits of positive affect on visual information processing and we are still searching for a better paradigm for future work on neural imaging.

Issue B: Mood effect on visual information processing

Positive psychology is considered by many researchers as one of the four cutting-edge research fields in the 21st-century psychology (Smith, Nolen-Hoeksema, Fredrickson, & Loftus, 2003). Positive affect benefits cognition by broadening perception, attention, cognition, and action (see Fredrickson, 2003). For example, positive affect increases the scope of attention (Fredrickson & Branigan, 2005; Rowe, Hirsh, & Anderson, 2007), the problem-solving ability (Greene & Noice, 1988), and decision making (see Isen, 1993). Positive affect may be experienced as efficacy feedback that prompted participants to activate their goals (Storbeck & Clore, 2007). The affective feedback can regulate attention and tune cognitive processes to meet task demands (Clore & Hunrainfwe, 2007). However, some studies showed opposite findings. For example, Oaksford, Morris, Grainger, Williams and Mark (1996) found positive affect impaired performance on tasks that require executive control.

We focus on the impact of positive affect on selective attention in the current project. Affect is typically induced by mood manipulation such as watching different types of films

(Rottenberg, Ray, & Gross, 2007), photos of different emotionality (Bradley & Lang, 2007), or combining music with thought (Eich, Ng, Macaulay, Percy, & Grebneva, 2007). Our interest is to uncover the mechanisms that underlie the impact of positive affect on selective attention. To achieve this goal, we first clarified the effect of positive affect on selective attention because inconsistent results have been observed.

Manipulating the response compatibility of two flanking distractors to target selection and the target-distractor distance in a flanker task (Eriksen & Eriksen, 1974), Rowe et al. (2007) found that positive affect increased the breadth of attentional selection. The effect of distractor compatibility on target selection remained significant across three levels of target-distractor distance under positive mood. In contrast, the compatibility effect was reduced under neutral mood when the distractors were further away from the target. Attentional focus was wider under positive mood than under neutral mood.

Gable and Harmon-Jones (2008) found that positive-approach motivation decreased rather than increasing attentional breadth using variants of a global-local task (Navon, 1977). In this task, performance can be based on information at the global level or at the local level. For example, participants see three stimuli on each trial with one as the reference target and the other two as the comparison stimuli. Their task is to select which comparison stimulus is more similar to the reference target. The reference targets consist of both global and local shapes (e.g. a triangle made of three smaller squares). One of the comparison stimuli shares the same global shape (a triangle made of three smaller triangles) while the other shares the same local shape (a square made of four smaller squares). A global precedence, biasing toward selecting global information in response, was observed under low-approach positive mood (inducing by watching a film which showed cats in humorous situations) and also under neutral mood (inducing by showing photos of rocks). The bias was reduced under positive-approach mood (inducing by watching a film or photos of delicious desserts). No comparison was made between conditions of low-approach positive mood and neutral mood.

In contrast, two studies (Baumann & Kuhl, 2005; Tan, Jones, & Watson, 2009) have shown that the element of approach motivation may not be necessary to reduce global precedence in global-local tasks. Tan et al. (2009) primed neutral, positive, or negative words prior to showing participants a global-local stimulus on each trial. They found that positive-affect priming can reduce global precedence in comparison with neutral priming for participants who were biased toward global focus under neutral mood. The positive words used in this study were the follows: calm, rejoice, dawn, compliment, life, and truth. Not all of these words are related to approach motivation. The same pattern of results was observed when photos of positive emotionality were used as primes, and several photos were unrelated to approach motivation.

It is likely that a common mechanism underlies both the findings of broadening and narrowing the focus of attention in the two task contexts. Manipulating distractor compatibility in a set switching paradigm, Dreisbach and Goschke (2004) found that positive affect modulated the balance between the stability and flexibility of cognitive set. In comparison with neutral or negative affect, positive affect promoted flexibility via reducing the tendency of perseveration when switching was required. Yet, the flexibility came with a cost by increasing the effect of distractor compatibility. It is likely that positive affect increases the processing of the lesser salient information which is the task-irrelevant distractors in a flanker task. As a result, the scope of attention was broad and the distractor compatibility remained significant even when distractors were farther away. Similarly, local information is the less salient feature in global-local processes. The processing of the lesser salient local information can lead to the reduction of global precedence and, hence, narrowing attention to local level. We refer to this postulation in the latter text as the *distractibility* hypothesis.

Alternatively, relational processing may mediate the impact of positive affect on the breadth of attentional selection. It has been suggested that positive affect leads to relational processing (Clore & Hunrainfwe, 2007). It is likely that people under positive emotion adopt the relational processing to associate the target and the distractors in the flanker task paradigm. As a result, far distractors are still processed under positive mood. On the similar base, relational processing can account for the reduction of global precedence in the local-global task context by suggesting that relational processing prompts grouping of local elements so that local information becomes more salient. We refer to this postulation in the latter text as the *relational-processing* hypothesis. We tested these two alternative hypotheses in different stimulus-task contexts: a modified global-local task and a dynamic multiple-object-tracking (MOT) task. A total of five experiments have been conducted. We describe details of each experiment as the follows.

Experiment 1

The purpose of this experiment was two folds: to assure that the method for inducing positive mood is effective and to test whether the reduction of global precedence results from distractibility or from relational processing of local elements. Given that film watching is a typical method to induce mood (Rottenberg et al., 2007), we selected two films with one showing walking through a furniture store and the other showing a humorous event. We tested whether positive mood can encourage the processing of local information in judging modified global-local stimuli.

A typical global-local stimulus consists of incongruent global and local information for researchers to investigate whether participants are biased toward selecting global information and whether the global precedence can be reduced after positive affective priming or after induction of positive mood. Given the incongruency in the global-local information, it is likely that the processing of local information under positive mood results from distractibility or relational processing of local elements. To examine which mechanism underlies previous findings, we incorporated the manipulation of global-local congruency. If reduction of global precedence results from distractibility, we should observe an interaction between mood and the global-local compatibility. There should be no mood effect when information is congruent between the two levels because local information does not cause distraction. Reaction times in the incongruent condition should be longer under positive mood than under neutral mood because of the distraction to local information elicits response conflict to global selection. The relational-processing hypothesis also predicts slower reaction times under positive mood than under neutral mood in the incongruent condition because of grouping local elements would elevate the conflict in selection. The difference lies in the congruent condition. The relational-processing hypothesis predicts faster response times under positive mood than under neutral mood because relational processing of local elements instigates the same overt response as target response.

Method

Participants. Seventeen college students volunteered in the experiment and they received monetary rewards (about US $5) for participation. All participants have normal or corrected-to-normal vision; they were naïve to the purpose of the experiment.

Task, stimuli, and design. Participants' task was to judge what they saw on screen, between the digit 6 and the digit 9. Four global-local stimuli were constructed. Each global digit was approximately 5.39˚, consisting of local digits that were 0.4˚ each at a viewing distance of 62 cm. The local digits are the same as the global digit in the congruent condition (Figure 1a); the two are different digits in the incongruent condition (Figure 1b).

Insert Figure 1 about here

With the manipulation of global-local congruency, the experiment followed a 2 (mood) x 2 (global-local congruency) x 60 (replication) within-subjects factorial design. The experiment was divided into two blocks, with 120 trials in each. Mood induction was manipulated between blocks, with the order constant so that participants performed the task under neutral mood in the first block and under positive mood in the second block. Thus, the effect of positive mood would not carry over to the effect of neural mood. The order of global-local congruency manipulation was randomized in each block.

Procedure

Participants rated their current mood after signing the consent form as the baseline before watching a neutral-affect film. Mood rating was collected on 16 items using a 7-point Likert scale. The 16 items consisted of 8 adjectives describing positive mood (playful, happy, desiring, joyful, calm, contended, entertaining, and excited) and 8 adjectives describing negative mood (annoyed, frustrated, sad, disgusted, angry, anxious, discouraged, and scared).

After watching a neutral-affect film, they rated their mood again. Participants then performed the global-local task for 120 trials with a rest at the end of every 40 trials.

On each trial, a fixation was first shown for 500 ms. A global-local stimulus was then presented until response and the inter-trial interval was 500 ms. Participants pressed the numeric key (6 or 9) for entering their judgment.

Participants were asked to rest after completing the first block. After a rest period, participants rated their mood as the baseline before mood induction, watched a positive-affect film, and rated mood on 16 items. They then performed the task in another block of 120 trials with a rest every 40 trials.

Results

Mood rating. The averaged score of the positive-affect items and the averaged score of the negative-affect items were analyzed separately using paired *t* tests. Participants' mood did not change after watching the neural film (*p*s > .2). Participants' rating on the positive-affect items significantly increased, $t(16) = 5.52$, $p < .01$ (before induction: 3.96 ± .23; after induction: 4.68 ± .23) and their rating on the negative-affect items significantly decreased, $t(16) = -3.10$, $p < .05$ (before induction: 1.68 ± .21; after induction: 1.41 ± .19) after watching the humorous film. Mood induction was successful.

Global-local judgment. Two dependent variables were used in analysis. The first one was the proportion of global judgment that reflects the bias toward processing global information. The second dependent variable was reaction times (RTs) of all trials because participants were free to choose their responses. Table 1 shows the mean performance in each condition. Performance on each dependent variable was analyzed using a 2 (mood) x 2 (global-local congruency) repeated-measures analysis of variance (ANOVA).

The results based on global bias showed a significant congruency effect [$F(1,16) = 11.74$, $p < .005$, $\eta_p^2 = .42$], with a lesser global precedence (.77 ± .07) in the incongruent condition than in the congruent condition (.98 ± .01). No other effects reached significance (*p*s > .3). Analysis of RTs showed a significant main effect of mood [$F(1,16) = 19.81$, $p < .001$, $\eta_p^2 = .55$], a significant main effect of global-local congruency [$F(1,16) = 12.71$, $p < .005$, $\eta_p^2 = .44$], and a significant interaction effect [$F(1,16) = 7.14$, $p < .05$, $\eta_p^2 = .31$]. As shown in Figure 2, congruency effect was smaller under positive mood [$F(1,32) = 5.0$, $p < .05$, $\eta_p^2 = .14$] than under neutral mood [$F(1,32) = 18.72$, $p < .001$, $\eta_p^2 = .37$]. The mood effect was larger in the incongruent condition [$F(1,32) = 26.72$, $p < .001$, $\eta_p^2 = .46$] than in the congruent condition [$F(1,32) = 7.92$, $p < .01$, $\eta_p^2 = .20$]. Participants responded faster under positive mood and the efficiency reduced the interference effect in the incongruent condition to a greater extent in comparison with the congruent condition.

Insert Table 1 and Figure 2 about here

Discussion

The results replicated previous findings of global precedence in the perception of global-local stimuli. Participants chose to report the global digits in majority of the trials. This global bias was reduced when local information activated response conflict. The results also showed that positive mood improved performance and reduced the influence of local information on task performance. Participants were faster in judgment under positive mood and the improvement was greater in the incongruent condition than in the congruent condition. The results did not support the distractibility hypothesis which predicts greater interference under positive mood. Neither did the results support the relational processing, which predicts faster RTs in the congruent condition and longer RTs in the incongruent condition under positive mood as compared with RTs under neutral mood. Positive mood reduced the impact of conflicting global-local information on judgment.

Experiment 2A

The results of Experiment 1 showed efficient processing under positive mood and the impact on visual processing was greater in the incongruent condition. The results suggest that participants could ignore the global-local incongruency in judgment under positive mood. That is, participants were more flexible in the global-local processes under positive mood.

In Experiment 1, participants were free to choose between the global and local levels of processing to make a judgment. This freedom of choice may have prompted the strategy of adopting the most efficient process under positive mood. The objective of this experiment was to replicate the results in a different task context where the locus of visual selection was defined for the participants. Participants were specifically instructed to attend to the global or local aspect of the stimuli.

Method

Participants. Twenty college students volunteered in the experiment and they received monetary rewards (about US $5) for participation. All participants have normal or corrected-to-normal vision; they were naïve to the purpose of the experiment.

Task, stimuli, design, and procedure. All aspects were similar to those of Experiment 1, except that a large or small square box was imposed on the stimuli (see Figure 3) for the manipulation of a task demand variable. When a large square box was shown, participants were required to report the large digit; participants reported the local digit when a small square box was shown with the stimuli. Thus, the design was a 2 (mood) x 2 (task demand) x 2 (global-local congruency) x 30 (replication) within-subjects factorial design. The order of mood induction was constant between two blocks, with neutral mood in the first block and positive mood in the second block of 120 trials. The manipulations of task demand and global-local congruency were randomized within each block.

Insert Figure 3 about here

Results

Mood rating. The averaged score of the positive-affect items and the averaged score of the negative-affect items were analyzed separately using paired *t* tests. Participants' positive mood did not change after watching the neural film ($p > .6$) but their negative mood decreased after watching the film, $t(19) = -3.11$, $p < .01$ (before induction: 1.87 ± .23; after induction: 1.53 ± .17). Participants' rating on the positive-affect items increased, $t(19) = 3.46$, $p < .005$ (before induction: 3.74 ± .28; after induction: 4.70 ± .27) and their rating on the negative-affect items decreased after watching the humorous film, $t(19) = 2.25$, $p < .05$ (before induction: 1.51 ± .16; after induction: 1.31 ± .11). Although participants' mood was less negative after watching a neutral film, their overall mood was more positive and less negative after watching a humorous film. Mood induction was successful.

Global-local judgment. Table 2 shows the mean performance in each condition. A 2 (mood) x 2 (task demand) x 2 (global-local congruency) repeated-measures ANOVA was conducted on proportion of correct responses. The results showed a significant main effect of global-local congruency [$F(1,19) = 5.30$, $p < .05$, $\eta_p^2 = .22$], with a better performance in the congruent condition (.99 ± .008) than in the incongruent condition (.97 ± .01). No other effects reached significance in accuracy data (*p*s > .1). The analysis of RTs of correct responses showed that the main effect of mood was significant [$F(1,19) = 18.59$, $p < .001$, $\eta_p^2 = .49$], with a faster mean RT under positive mood (423.72 ms ± 16.04) than under neutral mood (454.64 ms ± 20.89). The main effect of global-local congruency was also significant [$F(1,19) = 88.06$, $p < .001$, $\eta_p^2 = .82$], with a faster mean RT in the congruent condition (425.78 ms ± 18.58) than in the incongruent condition (452.58 ms ±18.83). The main effect of task demand was marginal ($p < .1$) and none of the interaction effects reached significance (*p*s > .3). Positive mood did not alter the effect of global-local congruency onperformance.

Insert Table 2 about here

Discussion

Global-local congruency influenced judgment, reflecting that information at both levels was processed regardless of task demand. Performance was better when local information was congruent with the global information than when local information elicits conflict in response selection with judgment based on global information. Participants were better at judgment under positive mood than under neutral affect, but positive mood did not modulate the global-local congruency effect. This null finding is somewhat surprising especially when the task performance relies on the local information. According to the broaden-and-build theory (Fredrickson, 2001), positive mood should broaden the scope of attention to the global level as observed in previous studies (Fredrickson & Branigan, 2005; Rowe et al., 2007). If attentional focus was broad under positive mood than under neutral mood, response interference activated by the global information in the incongruent condition should be greater in the former than the latter context when the task demand required local processes in reporting the local digit inside the small box. The results did not support this prediction. It appears that by specifying the level of processing in visual selection the impact of positive mood on global-local processes is eliminated.

Experiment 2B

The results of Experiments 1 and 2A showed that participants were better at global-local judgment under positive mood than under neutral mood. However, the order of mood induction was kept constant to avoid the carry-over effect from positive mood to neutral mood. The efficient processing may have resulted from practice effect. To verify whether efficient processing of task-relevant information results from mood manipulation or from practice, we repeated Experiment 2A with induction of neutral mood in both blocks of the experiment. If efficient processing results from practice effect, we should observe better performance in the second block. All aspects were the same as in Experiment 2A except that two neutral-affect films were used in this experiment.

Method

Participants. Twenty college students volunteered in the experiment and they received monetary rewards (about US $5) for participation. All participants have normal or corrected-to-normal vision; they were naïve to the purpose of the experiment.

Task, stimuli, design, and procedure. All aspects were the same as in Experiment 2A. The only difference was that participants watched another neutral-affect film before performing the task in the second block of the experiment.

Results

Mood rating. The averaged score of the positive-affect items and the averaged score of the negative-affect items were analyzed separately using paired *t* tests. Except in the first block, participants' mood did not change after watching both neural-affect films (*p*s > .1). Participants' negative mood significantly decreased, $t(19) = -3.28$, $p < .01$ (before induction: 1.80 ± .21; after induction: 1.48 ± .14) after watching the first neutral-affect film.

Global-local judgment. Table 3 shows the mean performance in each condition. A 2 (order: first or second block) x 2 (task demand) x 2 (global-local congruency) repeated-measures ANOVA was conducted on accuracy. The results showed that the global-local congruency effect on accuracy was marginal ($p < .1$) while no other effects reached significance (*p*s > .1). The analysis of RTs of correct responses showed that the main effect of order was significant [$F(1,19) = 6.57$, $p < .01$, $\eta_p^2 = .26$], with a faster mean RT in the second block (410.48 ms ± 15.86) than in the first block (433.70 ms ± 16.08). The main effect of global-local congruency was significant [$F(1,19) = 60.70$, $p < .001$, $\eta_p^2 = .76$], with a faster mean RT in the congruent condition (410.57 ms ± 15.28) than in the incongruent condition (433.61 ms ±16.64). The main effect of task demand was also significant [$F(1,19) = 6.76$, $p < .05$, $\eta_p^2 = .26$], with a faster mean RT in judging the global digit (410.07 ms ± 14.38) than in judging the local digit (434.17 ms ±17.38). None of the interaction effects reached significance (*p*s > .2).

Insert Table 3 about here

Discussion

Participants were better at judgment when both the global and local information elicited the same response selection in the congruent condition than when the two levels activated conflicting responses. More importantly, performance was better in the second block than in the first block, showing the practice effect. Thus, the efficiency in the global-local processes observed in Experiment 1 and Experiment 2A cannot be accounted for solely by positive mood. The interaction effect observed in Experiment 1 may simply arise from the ability to ignore global-local congruency after practice when participants were free to choose the information to process. When participants were required to judge a specific level of information in Experiment 2A, practice effect had led to efficient processing. It appears that both global and local information is processed no matter whether participants were in a neutral or positive mood.

Experiment 3

The results of Experiments 1 and 2 did not show a significant effect of positive mood on global-local processes. Global precedence in visual processing was observed and the magnitude was not altered by mood manipulation. It is likely that positive mood did not last long enough after watching the film to sustain its effect on visual processing over time. Thus, we adopted the priming method as used in Baumann and Kuhl's (2005) study and also in Tan et al.'s (2009) Experiment 1. With this method, a prime word preceded each global-local judgment. The results of previous two studies showed that positive affective priming encouraged the processing of the perceptual underdog, that is, the lesser salient information. For participants who adopted a global focus, local information is the underdog; global information is the underdog for participants who adopted a local focus.

Method

Participants. Seventeen college students volunteered in the experiment and they received monetary rewards (about US $5) for participation. All participants have normal or corrected-to-normal vision; they were naïve to the purpose of the experiment.

Task, stimuli, design, and procedure. All aspects were similar to those of Experiment 2, except that the method of affective priming was adopted and negative-affect prime words were included. Thus, the design followed a 3 (mood: neutral, positive, negative) x 2 (task demand: global, local) x 2 (global-local congruency) x 24 (replication) within-subjects factorial design. Manipulations of all variables were randomized across trials. On each trial, a fixation was first shown for 500 ms and a prime word of neutral, positive, or negative emotionality was then shown for 400 ms. After a blank interval of 500 ms, a global-local stimulus was presented until the participant responded. Participants could rest at the end of 144 trials.

Results

Table 4 shows mean performance in each condition. A 3 (mood) x 2 (task demand) x 2 (global-local congruency) repeated-measures ANOVA was conducted. The results based on accuracy data showed a significant main effect of global-local congruency [$F(1, 16) = 10.13$, $p < .01$, $\eta_p^2 = .38$], with higher accuracy in the congruent condition (.98 ± .009) than in the incongruent condition (.97 ± .01). The interaction effect between mood and task demand was also significant [$F(2, 32) = 3.45$, $p < .05$, $\eta_p^2 = .15$]. This interaction arose because mood did not affect performance when judging global digits ($p > .6$) and significantly influenced performance when judging local digits [$F(2, 64) = 4.61$, $p < .05$, $\eta_p^2 = .12$]. Figure 4a shows this interaction effect, with lower accuracy under neutral mood than under either positive or negative mood. The results on RT data showed a significant main effect of congruency [$F(1,14) = 28.78$, $p < .001$, $\eta_p^2 = .67$] and a significant interaction between task demand and global-local congruency [$F(1,14) = 6.54$, $p < .05$, $\eta_p^2 = .32$]. As shown in Figure 4b, the interaction arose because the congruency effect was larger in making a global judgment than making a local judgment.

Insert Table 4 and Figure 4 about here

Discussion

Mood manipulation via affective priming influenced performance accuracy only when participants judged the local digit inside the small box. Participants were more accurate after negative- and positive-affect priming. This improvement in performance accuracy may have resulted from higher arousal after affective priming. With a higher level of arousal, participants could better focus their attention on the small box, reducing the influence of global information. Mood manipulation did not influence RTs. This finding is inconsistent with the suggestion that positive affect can broaden the scope of attention (Fredrickson & Branigan, 2005; Rowe et al., 2007).

Tan et al. (2009) have suggested that individual differences in the focus of attention play a role in the effect of positive-affect priming on global-local processes. For participants who adopt global focus, local information is the perceptual underdog and positive-affect priming can encourage local processing. For participants who adopt local focus, global information is the perceptual underdog and positive-affect priming can encourage global processing. Thus, null results of positive-affect priming were observed when data from all participants were analyzed. Significant results were found only when data from the two groups were separately analyzed.

To explore whether individual differences influenced the null results of the current experiment, we first computed the magnitude of the compatibility effect in judging the global digits under neutral mood for each participant. We then used the median magnitude to split participants into two groups. A smaller compatibility effect suggests that participants were less influenced by the local information when judging the global digits. Thus, the group with a smaller compatibility effect was classified as the global group and the group with a larger compatibility effect classified as the non-global group. We did not observe the encouragement of processing perceptual underdog in global-local processes in either group.

The major difference between this experiment and the two studies that used affective priming (Baumann & Kuhl, 2005; Tan et al., 2009) is the manipulation of task demand. In the previous studies that observed an effect of positive-affect priming on global-local judgment, participants were told to search for the presence of a target (e.g., circle). In 25% of the trials, global information suffices for the judgment (e.g., a circle made of small triangles); in 25% of trials, local information indicates the target (a square made of small circles). The focus of attention was not specified by the task demand and participants could freely alter their focal attention. In the current experiment, the focus of attention was designated by the size of the box. It appears that positive affect did not alter participants' focus of attention nor modulate global-local processes in the current task context where the task rule defines the focus of attention.

Summary

Results from four experiments did not clearly show any effect of positive mood on visual information processing except that both positive mood and negative mood can improve performance accuracy when judging a local digit inside a small box (Experiment 3). This result suggests that affect as compared with the neutral mood can narrow the focus of attention to the small box and reduce the influence of the global information. This improvement may have resulted from increasing arousal level by affective priming. Positive mood does not broaden the focus of attention as the broaden-and-build theory (Fredrickson, 2001) suggests. Neither does positive mood encourage the processing of nonpreferred global-local processes as previous studies (Baumann & Kuhl, 2005; Tan et al., 2009) have observed.

Given that the priming method used in Experiment 3 was the same as the method used in two previous studies that observed priming effects on global-local processes, we consider three factors that may have caused the difference in findings. First, the sample size of Experiment 3 (N = 17) was much smaller than the sample sizes used in the previous two studies (N = 78 in Baumann and Kuhl's study and N = 64 in Tan et al.'s study). To resolve this inconsistency, we will increase the sample size of Experiment 3. Second, the cultural differences in emotional experience and control may have led to inconsistent findings. Several studies (Le, Berenbaum, & Raghavan, 2002; Mesquita Karasawa, 2002; Tsai & Levenson, 1997) have shown that Asian participants and Asian American participants differ from European American participants in emotional experience and behavior. To explore this possibility, we will replicate Tan et al.'s Experiment 1. The third factor is the difference in task context. We consider this factor the most likely variable that causes inconsistent results. Positive affect modulate global-local processes only when the task rule does not require a specific attentional set. When the task rule requires a specific attentional set, positive affect has no influence. We will conduct another experiment in which attentional set is manipulated to corroborate our hypothesis.

Issue C: Mood effect on tracking multiple objects

This part of the project was carried out in parallel with Issue B as we described in the previous progress report. We first used the multiple-object tracking (MOT) task to investigate mood effect on tracking performance. The objective was to investigate how mood may influence performance in a dynamic environment such as fighting in an air battle.

Experiment 1

The objective of this experiment was to investigate whether mood would affect the capacity limitation of visual information processing in a dynamic task context. Human information processing is limited in capacity. The limitation manifests at different levels including perceptual attention (Lavie & Cox, 1997), visual working memory (Cowan, 2001; Luck & Vogel, 1997; Xu & Chun, 2006), and executive focus of attention (Oberauer, 2002). In a dynamic visual environment where objects constantly move, such capacity limitation exists in terms of the number of objects that observers can control (Fougnie & Marois, 2006; McKeeff, Remus, & Tong, 2007; Oksama & Hyona, 2008; Pylyshyn, 2002; Pylyshyn & Storm, 1988). Temporal limitation also exists in attentional selection (Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992). Thus, the speed of moving objects affects the ability for human observers to track multiple objects in the visual environment (Oksama & Hyona, 2008).

In two pilot experiments (see Appendix for a summary of the experiments), we examined the capacity limitation and whether grouping can reduce the limitation. We replicated previous findings that participants can track about four or five objects in a MOT task (Pylyshyn & Storm, 1988) and also observed the role of target-distractor confusion in

MOT performance. When four of five targets moved at a speed similar to the distractors', it was more likely for the participants to lose track of these targets compared with a lone target that moved at a different speed.

In this experiment, we examined whether mood can influence MOT performance. According to the distractibility hypothesis, participants should be distracted more easily under positive mood and, hence, MOT performance should be worse as compared with neutral mood. According to the relational-processing hypothesis, participants should be biased toward adopting a grouping strategy. If the grouping strategy is undertaken to relate the tracking targets, MOT performance should improve. Alternatively, mood may increase the arousal level as indicated by the results of Experiment 3 in the previous series.

We tested whether grouping and high arousal lead to a bias toward tracking targets moving at a faster speed because a previous study (Fencsik, Urrea, Place, Wolfe, & Horowitz, 2006) found that participants' tracking performance was better when targets moved at a speed faster than the distractors. Thus, we constructed three conditions. In the baseline condition, all six targets moved at different speeds. In the *fast* condition, four of the six targets moved at a faster speed than the other two targets. In the *slow* condition, four of the targets moved at a slower speed than the other two targets. If there is any bias toward selecting the fast targets, we should observe better performance in the fast condition than in the baseline condition which in turn is better than the slow condition.

Method

Participants. Thirty three college students volunteered in the experiment and they received monetary rewards (about US $5) for participation. All participants have normal or corrected-to-normal vision; they were naïve to the purpose of the experiment.

Stimuli and design. The MOT task was implemented by a Visual C++ program. Twelve gray circular discs were used as stimuli, with 0.92° (diameter) each within a box frame (14.9° x 14.9°) at a viewing distance of 62 cm. The initial position of each disc was randomly generated. On each trial, six were randomly selected to be the targets and six were the distractors. All distractors moved at the same speed (6.63°/s). In the baseline condition, all six targets moved at different speeds (9.47°/s, 7.37°/s, 6.03°/s, 5.10°/s, 4.42°/s, 3.90°/s). In the fast condition, four of the six targets moved at a faster speed (7.37°/s) than the other two targets (4.42°). In the slow condition, four of the targets moved at a slower speed (4.42°) than the other two targets (7.37°/s).

The initial movement direction of each disc was randomly selected from eight possible directions (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°, with vertical direction as 0°). Each disc moved in the selected direction for a duration that was randomly selected from a range of 35 ms to 100 ms before it altered direction. The direction was then randomly selected from three possible choices (the original direction and its two neighborhood directions) to avoid a large change in movement direction that may capture attention. The movement direction was also altered when the disc hit the frame boundary or when the disc collided with another disc. Each time a disc altered movement direction, the duration of the new direction was again randomly selected.

Mood induction was manipulated between subjects. One group of participants was randomly assigned to view a neutral-affect film before performing the MOT task; one group viewed a positive-affect film; the third group received intermittent false positive feedback that was used to encourage the feeling of task efficacy. For all groups, the order of conditions was randomized. There were 20 observations in each condition.

Procedure

All participants first rated their mood on 16 items (8 for positive, 8 for negative). Participants in the neutral- and positive-mood groups then watched a film and rated their mood again after watching the film. Participants then performed the MOT task for 60 trials with a rest at the end of every 20 trials. On each trial, a "Ready?" message was first shown on screen. After participants pressed a space bar, 12 discs were shown and six targets flashed in white for 2 sec. All discs then moved for 5 sec. Participants were instructed to track these targets until the end of trial when all discs stop motion. At this moment, alphanumeric symbols (1-10, A, B) were shown in the discs and participants were required to enter the symbols of the six targets. Participants were told to be as accurate as possible without worrying about the response time. For participants in the feedback group, feedback was provided at the end of every 20 trials. Feedback messages informed participants that their performance was ranked the top 5-10% of the sample and they were congratulated for a job well done. For the feedback group, the second round of mood ratings was collected at the end of the experiment.

Results

Mood rating. Neither positive-affect film nor false feedback influenced mood ratings (*p*s $> .1$). In contrast, ratings on positive mood increased after watching a neutral-affect film, $t(8) = 2.52$, $p < .05$ (before induction: 3.99 ± .22; after induction: 4.33 ± .31). Participants' ratings on negative mood decreased after watching the neutral-affect film, $t(8) = -2.13$, $p < .05$ (before induction: 1.54 ± .17; after induction: 1.35 ± .16). Mood induction failed.

MOT performance. The results did not show any effect of mood induction or condition (*p*s $> .1$). In all three mood conditions, participants accurately tracked about four targets (Neutral: 3.97, Positive mood: 3.97, Feedback: 3.93).

Discussion

The mood induction failed to produce the expected effects. We are unable to explain why participants experienced a better mood after watching a neutral-affect film which was also used in previous experiments. It could be due to the failure in mood induction, null results were observed on tracking performance. Post-experiment interviews with participants suggested that the MOT task was too difficult for the majority of the participants and task difficulty may have eliminated the effect of condition and also the effect of false feedback. Participants in general felt frustrated because they were unable to perform the task well.

Summary

Mood induction by watching films failed in this experiment. Therefore, there was no point to continue the experiment as designed. Another problem encountered was to find an optimal number of targets for the participants to track in the baseline condition. The results from our pilot experiments showed that some participants could accurately track five targets and the majority of the participants could accurately track four targets. To avoid ceiling effects and the opportunity to observe performance improvement, we chose six targets in designing this experiment. This choice appears to be not optimal because participants felt frustrated when they failed to track all targets. We are currently searching for a solution.

References

Baumann, N., & Kuhl, J. (2005). Positive affect and flexibility: overcoming the precedence of global over local processing of visual information. *Motivation and Emotion, 29,* 123-134.

Bradley, M. M., & Lang, P. J. (2007). The international Affective Picture System (IAPS) in the study of emotion and attention. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment* (pp. 29-46). New York: Oxford University Press.

Broadbent, D. E., & Broadbent, M. H. P. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception & Psychophysics, 42,* 105-113.

Clore, G. L., & Hunrainfwe, J. R. (2007). How emotions inform judgment and regulate thought. *Trends in Cognitive Sciences, 11*, 9, 393-399.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24,* 87-185.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30*, 343-353.

Eich, E., Ng, J. T. W., Macaulay, D., Percy, A. D., & Grebneva, I. (2007). Combining music with thought to change mood. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment* (pp. 124-136). New York: Oxford University Press.

Eriksen, B. A., & Eriksen, C.W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception and Psychophysics, 16,* 143–149.

Fougnie, D., & Marois, R. (2006). Distinct Capacity Limits for Attention and Working Memory: Evidence From Attentive Tracking and Visual Working Memory Paradigms.

Psychological Science, 17(6), 526-534.

Fencsik, D. E., Urrea, J., Place, S. S., Wolfe, J. M., & Horowitz, T. S.（2006). Velocity cues improve visual search and multiple object tracking. *Visual Cognition, 14*(1), 92-95.

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist*, *56*, 218-226.

Fredrickson, B. L. (2003), The value of positive emotions, *American Scientist*, *91*, 330-335.

Fredrickson, B. L., & Branigan, C. (2005). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognitive and Emotion*, *19*, 313-332.

Gable, P.A., & Harmon-Jones，E．(2008). Approach-motivated positive affect reduces breadth of attention. *Psychological Science, 19,* 476-482.

Greene, T. R., & Noice, H. (1988). Influence of positive affect upon creative thinking and problem solving in children. *Psychological Reports, 63,* 895-898.

Isen, A. M. (1993). Positive affect and decision making. Handbook of emotions. In M. Lewis and J. M. Haviland (Eds). *Handbook of emotions (pp. 261-277)*. New York, NY, US: Guilford Press.

Lavie, N.,& Cox, S., (1997). On the efficiency of visual selective attention: efficient visual search leads to inefficient distractor rejection. *Psychological Science. 8,* 395–398.

Le, H.-N., Berenbaum, H., & Raghavan, C. (2002). Culture and alexithymia: mean levels, correlates and the role of parental socialization of emotions. *Emotion, 2(4)*, 341–360.

Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature, 390*, 279-281.

Mesquita, B. & Karasawa, M. (2002). Different emotional lives. *Cognition and Emotion, 16(1)*, 127–141.

McKeeff, T. J., Remus, D. A., & Tong, F. (2007). Temporal limitations in object processing across the human ventral visual pathway. *Journal of Neurophysiology, 98*(1), 382-393.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 9, 353–383.

Oaksford, M., Morris, F., Grainger, B., Williams, J. & Mark, G. (1996). Mood, reasoning, and central executive processes. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 22*, 476–492.

Oberauer, K. (2002). Access to information in working memory: Exploring the focus of attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 411–421.

Oksama, L., & Hyona, J. (2008). Dynamic binding of identity and location information: A serial model of multiple identity tracking. *Cognitive Psychology, 56*(4), 237-283.

Pylyshyn, Z. W. (2002). Visual indexes, preconceptual objects, and situated vision. *Objects and attention* (pp. 127-158). Cambridge, MA: MIT Press.

Pylyshyn, Z., W. & Storm, R., W. (1988). Tracking multiple independent targets: Evidence for a parallel tracking mechanism. *Spatial Vision 3*(3), 179 - 197.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18,* 849-860.

Rottenberg, J., Ray, R. D., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment* (pp. 9-28). New York: Oxford University Press.

Rowe, G., Hirsh, J. B., & Anderson, A. K. (2007). Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences U.S.A. ,104*, 383-388.

Smith, E., Nolen-Hoeksema, S., Fredrickson, B. L., & Loftus, G. R. (2003). *Atkinson & Hilgard's Introduction to Psychology 14th edition.* Beltmont, CA: Wadsworth/Thomson Learning.

Storbeck, J., & Clore, G. L. (2007). On the interdependence of cognition and emotion. *Cognition & Emotion*, *21*, 1212-1237.

Tan, H. K., Jones, G. V., & Watson, D. G. (2009). Encouraging the perceptual underdog: Positive affective priming of nonpreferred local-global processes. *Emotion*, *9*, 238-247.

Tsai, J. L. & Levenson, R. W. (1997). Cultural influences of emotional responding: Chinese American and European American dating couples during interpersonal conflict. *Journal of Cross-Cultural Psychology*, *28(5)*, 600–625.

Xu, Y., & Chun, M. M. (2006). Dissociable neural mechanisms supporting visual short-term memory for objects. *Nature, 440*(7080), 91-95.

Table 1

Mean performance in each condition of Experiment 1. Reaction time data included all trials because participants were free to judge the global or local digit. The proportion of biasing toward the global digit in judgment was used as another dependent variable.

Global-local congruency		Neutral mood	Positive mood
Congruent	Reaction time (ms)	482.44	430.53
	SD	137.19	102.32
	Global judgment (%)	98.10	97.40
	SD	2.13	2.81
Incongruent	Reaction time (ms)	572.43	477.03
	SD	207.20	150.43
	Global judgment (%)	76.50	78.00
	SD	23.19	27.07

Table 2

Mean performance in each condition of Experiment 2A where participants watched a neutral-affect film at the beginning of the first block and a positive-affect film at the beginning of the second block.

Global-local congruency		Neutral mood		Positive mood	
		Global	Local	Global	Local
Congruent	Reaction time (ms)	425.85	455.35	405.60	416.32
	SD	69.08	102.48	66.91	62.33
	Accuracy (%)	100.00	98.20	98.70	98.70
	SD	0.00	4.68	3.61	2.73
Incongruent	Reaction time (ms)	456.34	481.03	425.94	447.01
	SD	73.00	97.26	58.00	77.21
	Accuracy (%)	98.00	96.30	97.20	97.20
	SD	3.22	8.38	4.97	5.46

Table 3
Mean performance in each condition of Experiment 3 where participants watched a neutral-affect film at the beginning of both the first block and also in the beginning of the second block.

Global-local congruency		First half		Second half	
		Global	Local	Global	Local
Congruent	Reaction time (ms)	430.88	412.99	413.73	384.70
	SD	69.93	54.15	73.26	51.27
	Accuracy (%)	99.70	98.70	99.00	98.50
	SD	1.07	3.41	2.44	3.12
Incongruent	Reaction time (ms)	453.71	437.24	438.37	405.12
	SD	69.32	72.35	77.19	52.89
	Accuracy (%)	97.50	98.50	96.50	98.00
	SD	4.48	3.12	4.87	3.22

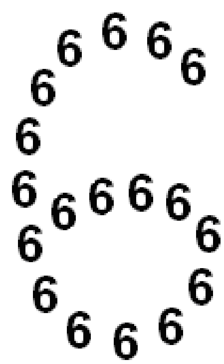
Table 4

Mean performance in each condition of Experiment 3 where affective priming was adopted to induce mood.

Global-local congruency		Global			Local		
		Neutral mood	Negative mood	Positive mood	Neutral mood	Negative mood	Positive mood
Congruent	Reaction time (ms)	391.83	397.22	397.81	419.30	418.30	408.90
	SD	48.36	64.04	65.24	106.24	88.42	60.38
	Accuracy (%)	98.60	98.80	98.40	96.40	98.60	98.60
	SD	2.33	2.23	2.72	5.34	2.91	2.91
Incongruent	Reaction time (ms)	434.86	418.63	422.35	418.18	429.74	438.74
	SD	68.92	60.11	76.46	66.40	83.63	95.81
	Accuracy (%)	96.40	96.60	96.50	97.20	98.10	97.90
	SD	6.31	4.66	3.98	3.69	2.33	2.72

Figure 1

(a) An example of the congruent stimuli used in Experiment 1.



(b) An example of the incongruent stimuli used in Experiment 1.

Figure 2
An interaction effect between mood and global-local congruency on judgment in Experiment 1. Positive mood improved performance efficiency and reduced global-local congruency effect on reaction times.

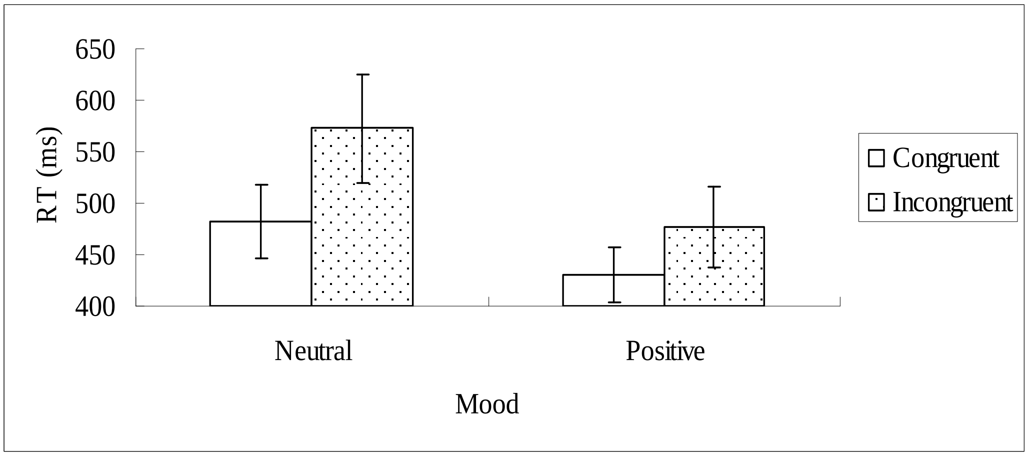
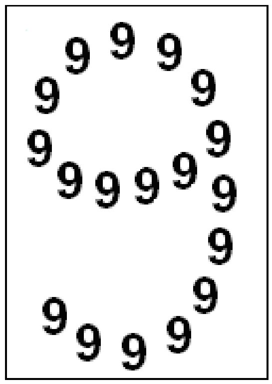


Figure 3

(a) An example of a congruent stimulus used in Experiment 2, with a large box outside to indicate that the task is to judge the global digit.



(b) An example of an incongruent stimulus used in Experiment 2, with a small box indicating that the task is to judge the local digit.

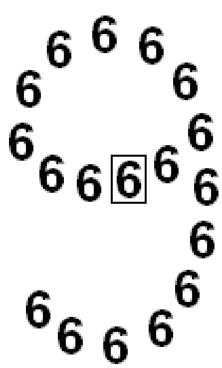
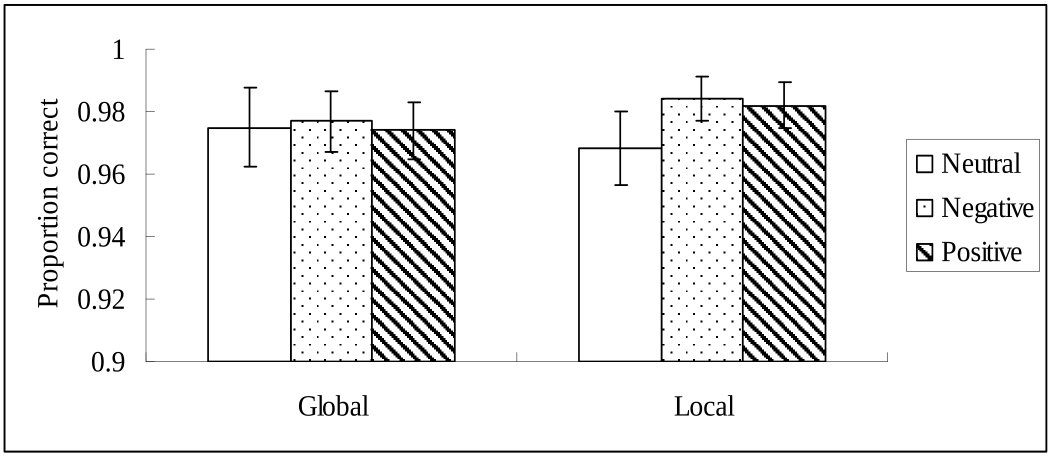
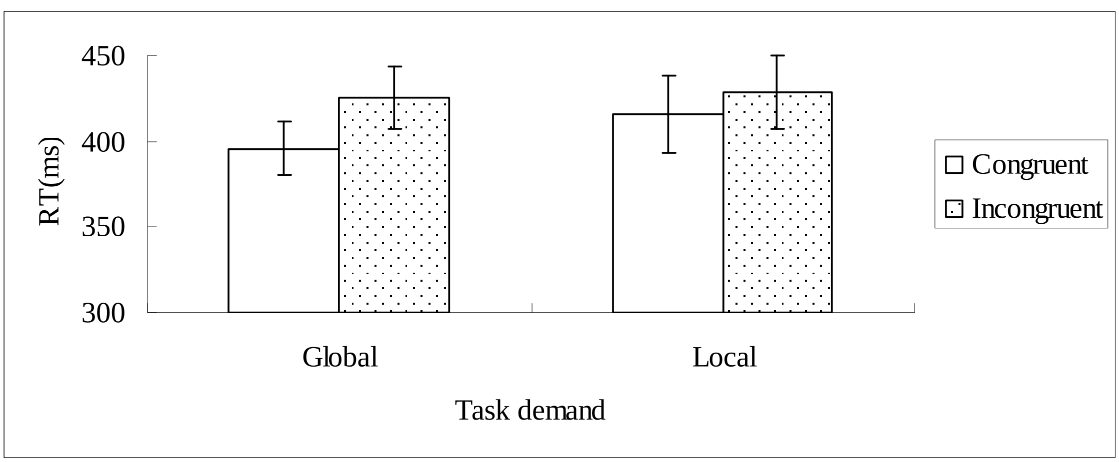


Figure 4

(a) An interaction effect, observed in Experiment 3, between mood and task demand on performance accuracy. Performance accuracy was higher under both positive and negative mood than under neutral mood when judging the local digit.



(b) An interaction effect, observed in Experiment 3, between task demand and global-local congruency on reaction times. Global-local congruency effect was smaller when judging the local digit than when judging the global digit.



Appendix: An abstract submitted to and accepted by the 17th annual meeting of Object, Perception, Attention, & Memory (OPAM) conference in Boston, November 19, 2009.

Strategic control through speed grouping in multiple object tracking

Pei-Chen Chiu
Dept. of Psychology, National Taiwan University
Yu-Wei Liao
Dept. of Psychology, National Taiwan University
Cheng-Ta Yang
Dept. of Psychology, National Taiwan University
Yei-Yu Yeh
Dept. of Psychology, National Taiwan University

Tracking dynamic objects is an important function for survival. An air traffic controller tracks multiple airplanes on the radar to ensure air safety. People attend to multiple moving cars while driving. The ability to attending to dynamic objects has been investigated by the Multiple Object Tracking (MOT) paradigm in which participants are required to track a number of target objects among similar distractors (Pylyshyn & Storm, 1988). Results showed that the ability is limited, as participants can accurately track only four or five targets. The capacity is lower when objects move at a fast speed (Oksama & Hyőnä, 2008); capacity is lower when participants must report the location of a specific target (Horowitz et al., 2007).

Object discriminability appears to affect tracking performance. Dennis and Pylyshyn (2002) found that object discriminability by color can improve performance. Horowitz et al. (2007) found that performance was better with unique cartoon animals than with identical ones. However, performance in tracking five targets among eight identical faces was better than tracking unique faces (Ren, Liu, Chen, & Fu, 2009). The worse performance in tracking unique faces may have resulted from difficult discrimination between target and nontarget faces. Horowitz et al. (2007) found equivalent performance between two conditions where all stimuli were identical and where there was an identical distractor for each of the unique targets. Makovski & Jiang (2008) suggested that the enhancement by distinctive features was confined to conditions where at least a single feature discriminated all objects. Tracking performance was not improved when a conjunction of features differentiated objects.

Discrimination on a single feature is important perhaps because of the ease in perceptual grouping of targets, the reduction of confusion when a target and a distractor move into proximity, or both. Yantis (1992) found that the ability to group targets together against

nontargets can improve tracking performance. Grouping can be formed through the initial configuration of the targets or through relative velocities between targets and nontargets. Tracking performance was better when there was a relative velocity gradient than when both targets and nontargets moved at the same velocity. Fencsik, Urrea, Place, Wolfe, & Horowitz (2006) replicated the results.

In the previous studies, distinctiveness was manipulated between targets and nontargets. No prior study has investigated what would happen if targets can also be differentiated into groups so that one target is more distinctive than the others from the nontargets. Would this distinctive target receive a higher attentional weight so that participants would maintain this target when they cannot track all the targets? Alternatively, would participants maximize performance by tracking the other homogenous targets? We examined this issue in Experiment 1.

In Experiment 1, all five nontargets moved at the same speed (6.63°/s). In the control condition, all five targets moved at different speeds (9.47°/s, 7.47°/s, 6.03°/s, 5.11°/s, 4.42°/s). In the experimental condition, one target moved at a faster speed (7.37°/s) and four targets moved in synchrony at a speed (6.03°/s) similar to nontargets'. The faster target is distinctive in speed against the nontargets. We examined the distribution of tracking errors when participants could accurately track four targets and missed one target.

The majority of 14 participants could accurately track four targets. In the control condition, the errors were equally distributed among targets. When there was no bias in the experimental condition, the conditional possibility that participants lost one of the four synchronized targets would be exactly four times as the conditional possibility that they lost the distinct target. We adopted a Bayesian approach to compare the ratio of the actual conditional probability of a target being lost to the expected conditional probability. A ratio of 1 reflects no bias. The results showed that the posterior probability was 69.3% for the ratio being larger than 1. The probability was higher (89.6%) among eight poor performers. Participants were biased toward dropping one of the four synchronized targets, moving at a speed similar to the nontargets'.

The similarity in movement speed may have activated perceptual grouping so that the synchronized targets were assigned the same attentional weight as the nontargets. In addition, participants may have confused the synchronized targets with the synchronized nontargets when objects move into proximity. As a result, one of the synchronized targets was lost more frequently than the distinctive target.

If grouping and confusion underlie the results of Experiment 1, one should be able to reduce the bias by ungrouping the synchronized targets and nontargets. We examined this hypothesis in Experiment 2. All remained the same as in Experiment 1 except that the nontargets moved at different speeds (6.03°/s, 6.22°/s, 6.42°/s, 6.86°/s and 6.94°/s) so that it should be difficult to group the synchronized targets with the nontargets or confuse the targets with the nontargets.

Another group of 14 participants volunteered in Experiment 2. The results showed no bias in the control condition. In the experimental condition, the Bayesian analysis showed that the posterior probability was 27.6% for the ratio between actual and expected conditional probabilities being larger than 1. The results remained the same across good and poor performers. The bias observed in Experiment 1 was eliminated. If there is any bias, the participants were bias toward maintaining the four synchronized targets.

When all nontargets moved at different speeds, the four synchronized targets would not be grouped or confused with the nontargets. Even moving at a faster speed, the lone target would not be distinctive. In contrast, the four synchronized targets can be grouped in tracking. And, the grouped unit would be distinctive from heterogeneous nontargets and the faster target. To maximize tracking performance, participants now maintain the grouped targets in dynamic attention.

In sum, the results of these two experiments showed how grouping and distinctiveness in speed can influence strategies used in tracking. When a lone target is distinctive because the other targets could be grouped with nontargets, this target would be maintained at higher probabilities. When a grouped unit of four targets is more distinctive, participants maintain these targets. Strategic control in dynamic tracking is possible through grouping.

References

Dennis, J. L., & Pylyshyn, Z. W., (2002). Effect of object discriminability on multiple object tracking. *Journal of Vision, 2*(7), 241a.

Fencsik, D. E., Urrea, J., Place, S. S., Wolfe, J. M., & Horowitz, T. S. (2006). Velocity cues improve visual search and multiple object tracking. *Visual Cognition, 14*(1), 92-95.

Horowitz, T. S., Klieger, S. B., Fencsik, D. E., Yang, K. K., Alvarez, G. A., & Wolfe, J. M. (2007). Tracking unique objects. *Perception & Psychophysics, 69*(2), 172-184.

Makovski, T., & Jiang, Y. V. (2008). Feature binding in attentive tracking of distinct objects. *Visual Cognition, 17*(1), 180 - 194.

Pylyshyn, Z. W., & Storm, R. W. (1988). Tracking multiple independent targets: Evidence for a parallel tracking mechanism. *Spatial Vision, 3*(3), 179-197.

Ren, D., Chen, W., Liu, C. H., & Fu, X. (2009). Identity processing in multiple-face tracking. *Journal of Vision*, *9(5):18*, 1-15.

Yantis, S. (1992). Multielement visual tracking: Attention and perceptual organization. *Cognitive Psychology, 24*(3), 295-340.