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Why not See: Inhibition on Distractors

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Abstract—**People often fail to see salient but unexpected objects in absorbing tasks. The present study was aimed to investigate the role of inhibitory mechanism for such attentional lapse. By manipulating similarity between distractors and unexpected objects, the first experiment shows the effect of inhibition in affecting the possibility of blindness. By reducing the number of distractors, the second experiment further suggests that there are different levels of inhibition. The two experiments together support the idea that inhibition on distractors as an attentional control influences the notice of unexpected objects. The findings provide implications for designing intelligent agents and systems.**

Keywords-inattentional blindness; inhibition; selective attention

I. INTRODUCTION

In everyday life, abundant visual stimuli impinge on our eyes, requiring selective attention to process relevant objects at the expense of irrelevant ones. At the same time, critical objects or events may happen in an unexpected way, resulting in unseen.

This phenomenon of "Inattentional Blindness" (IB) is a robust finding in studies on sustained attention [1-3]. People fail to see distinctive and salient objects or events, which is unexpected in the present visual task[4]. Based on Simon's video experiment [2], Most et al. [5] designed a computerized paradigm, in which participants were instructed to attend to the black objects and ignore the white objects, or vice versa. A red cross might move across the display in several seconds. In the end, one third of participants reported not to see the cross.

Most et al. interpreted this by stating that it was attentional set that mainly determinates noticing. Attentional set refers to the goal to concentrate on certain objects with specific properties, such as color, shape, etc. For instance, when observers are instructed to black objects, they are almost blind to white objects. This top-down control can override the capturing power of other irrelevant objects; even those were salient and distinctive. This idea is further supported by subsequent studies [6]. It proposes that the set "tunes" our attention to objects with specific features. If an object does not match the "set", no attentional capture happens.

The idea is intriguing; however, quite a few questions are still unclear. What is the "set" per se? Is it a positive reaction to targets, or a negative ignorance of distractors, or does it include both? There is a tendency to assume that when we turn our attention to task-relevant objects, we naturally ignore irrelevant ones. Therefore, two mechanisms are probably involved in the selective attention: one is to facilitate or amplify the information of relevant signals, the other is to inhibit or reduce the interference of irrelevant distractors [7]. Studies on negative priming [8, 9] have shown that the ignored objects are inhibited while targets are being attending to, thus the response to ignored ones would be hindered in the following presentation even when they become the targets. Choosing a target while successfully inhibiting distraction on distractors is an effective mechanism for selective attention [7, 9].

The opinion of inhibition on distractors is further supported by studies on sustained attention in dynamic events. Recently, Pylyshyn used a dot-probe paradigm to find that distractor inhibition in multiple object tracking may be attentional in nature [10].

Nevertheless, few studies have investigated the effect of such inhibition on sustained cognitive processing, particularly in the context of IB. It is not clear whether such inhibition on nontargets contributes to the ignorance of newly coming but unexpected objects.

Koivisto and Revonsuo claimed that there were no active ignoring of distractors in IB [11]. They manipulated the inhibitory level by changing the color of distractors. The underlying assumption was if the inhibition played a role in IB, then the more the distractors were like a target, the less likely would IB happen. The results showed noticing rate of unexpected objects was not related to such similarity. However, the changes of distractors may cause different attentional employment as in the original process of IB. The process on distractors which are in two-color may contain activation which weaken or override the inhibitory effect. Thus the results may be due to disturbed inhibition rather than purely activation. Furthermore, participants in the study were not required to move eyes, so the results may not reflect a real and natural attentional process in tracking multiple objects. In fact, an early study [12] provided preliminary attempts to support selective ignorance in causing IB. But the luminance distinctiveness possibly confounded the findings.

In the present study, we expected to modify Koivisto's experiment by directly manipulating the relationship between distractors and the unexpected object while controlling the original attention allocation. For this purpose, the targets and distractors were totally the same in different

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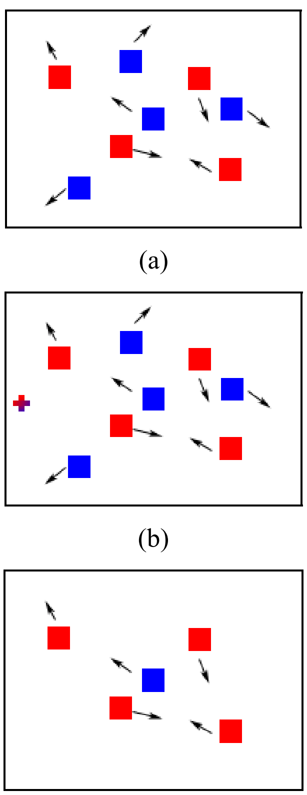
conditions, with just unexpected objects being changed. This was expected to ensure the same process of targets and distractors across groups. If inhibition contributed to inattentional blindness, the possibility of IB would rise with the increasing similarity of unexpected objects to the distractors.

II. GENERAL METHOD

A. Materials

Stimuli were presented with E-prime (a psychological research software) in a 22.58 × 16.93 cm (approximate 18◦ × 13◦) area with a gray background. Participants were seated in a lighted laboratory room. They sat at a comfortable distance from the computer screen. The refresh rate of the monitor was 85 Hz, and the resolution is 1024 × 768.

Fig.1 illustrates the stimulus. The targets and distractors were 1×1 cm squares. In both of the two experiments, the targets were four red squares; the distractors were blue squares, with four in experiment 1 and only one in experiment 2. The squares randomly bounced to the edges and then bounced off to a new direction. The bounces of targets was 9-12 in a 12s-trial. A cross in a 2mm thick was presented as the unexpected object. There were three colors of cross, red, blue, and two-color (the left half was red, and the right half was blue).



(a)

(b)

(c)

Figure 1. The stimulus in the experiment : (a) Squares moved independently, bouncing the edges. (b) A two-color cross as an unexpected object moved across the screen. (c) Only one distractor (blue) in experiment2

B. Design

According to the color of the cross, the participants in each experiment were distributed to three conditions: Blue Group, Red Group, and Two-Color Group.

In Blue Group, the unexpected object shared no similarity with the targets, but was in the same color as the distractors. According to our hypothesis, it was a group with inhibitory process to the unexpected object, the blindness should be obvious. As to the Red Group, the unexpected object was in the same color as the targets, so it must be processed by the attentional amplification. Thus the possibility of blindness in such condition should be low. By the same way, in the Two-Color Group, unexpected objects had features with both targets and distractors, so there should be inhibition on it, but the strength may be reduced by the facilitative processing. So it would show medium possibility of blindness, comparing to the possibility in the Blue Group.

C. Procedure

We applied the general procedure of inattentional blindness [13]. The observers were required to silently count the total number of bounces made by the red squares. At the end of each trial, observers were asked to enter the numbers of bounces. In the third trial, which was called the critical trial, a cross entered the display from the left at the fourth second, moved on a horizontal linear path, and exited from the right side of the frame. This passing lasted for approximately 4s.

After entering the bounces number, observers answered questions in response to a computerized prompt. The first one asked whether they had seen anything else in the gray area which did not existed in previous trials. Then, they were asked to make a choice on the detailed features (color, shape and direction of movement) of the new object they saw. They were required to guess if they reported not to see anything new.

Then the fourth trial was a divided-attention condition, observers were explicitly told to pay attention to both targets and the additional object, the questions in the trial was the same as in the critical trial. Followed was the full attentional trial, in which observers were told to find out the additional objects without counting bounces any more. The questions on the additional object were the same as previous trials. This trial was designed to ensure participants had understood and followed the task instructions.

D. Data Analysis

The criteria for noticing and index for counting error of each participant was computed as the methods used in Most et al.'s studies [12, 13]. If a participant who reported to see the new object was able to make at least one accurate choice for the detailed features, he/she was coded as noticer. The count error index was calculated as the absolute value of the difference between each count and the actual number of bounces and divided by the number of actual bounces on that trial. This index reflected the percentage error relative to the total number of actual bounces.

Due to our purpose to investigate the inhibition effect in causing IB, we mainly analyzed the responses in the critical trial. Chi-square test was conducted to test the difference in noticing rate between three groups. Because of the few noticing rate in some condition, Fisher's Exact Test was applied. ANOVA was applied to test the difference of count error.

III. Experiment

A. Experiment 1

1) Participants

54 participants were recruited for monetary rewards, but two failed to report seeing the cross in the full attentional trial. Therefore, 52 participants (26 females) were included in the final analysis. The average age was 23.02. They were divided into three groups: Blue Group (9 female, 8 male), Red Group (9 female, 9 male), and Two-color Group (8 female, 9 male). The age among the three group was not significantly different (F (2, 49) = 2.261, p = 0.115).

2) Results

Neither the noticing rate nor count error was significantly different across the three groups in non-critical trials. In the critical trial, the noticing rate was different between three groups (χ^2 = 21.306, p < 0.001). The Blue Group showed the lowest noticing rate (5.88%), while Red group showed highest noticing rate (77.78%) and 36.54% of people in Two-Color Group noticed the cross. The difference of count performance between three group was insignificant (F(2,49) = 0.413, p = 0.664).

Comparing the noticers' performance between three groups, the difference was significant (F(2,16) = 10.493, p = 0.001). The Blue Group showed the highest count error (0.62), while Red Group was 0.25 and two-color group was 0.22.

3) Discussion

The significant difference came from the specific processing in the critical trial, since the three groups did not show any significant difference in non-critical trials. The results from the Blue Group and Red Group are consistent with empirical IB studies, supporting the idea of attentional set. Moreover, the reduced noticing rate in the Two-Color Group reveals the effect of inhibition. If there are only attentional set to facilitate the processing on targets, the two-color cross with red color should also capture the attention as the red cross does. The fact is two-color is not as easily as red color to be seen. It seems that some mechanism hindered the facilitation brought by the target's color.

This appears to demonstrate the feature-based inhibition in causing IB. When the feature of distractors were inhibited, the objects with the same feature were difficult to capture attention. Contrarily, if the features in an additional object is as the same as in targets, it can capture observer's awareness. If the unexpected objects have both the inhibitory features and facilitating features, the noticing is hindered, comparing to the situation when there is only facilitation on it.

The similarity of the unexpected object to the distractors did not affect the primary task of counting. However, while considering only the noticers, the noticing affected counting task differently in the three groups. People in the Blue Group suffered largest disturbance. This can be explained by the attentional cost brought by the inhibition of distractors' features. Seeing the blue (distractor feature) should be at expense of the attentional resource which is supposed to compete with the inhibition. Thus the reduced performance in primary task is a result of attentional cost in activating the inhibitory processing.

B. Experiment2

Experiment 1 provided a preliminary evidence of the effect of inhibition on unexpected objects. However, it cannot exclude the possibility that it is the decreasing level of activation that contributes to the relatively low noticing rate in Two-Color Group. It may be difficult to directly separate the inhibitory and facilitative processes on the unexpected object, but we can influence one of the processes by manipulating other factors to see if such changes affect possibility of IB. We assumed that if the inhibition of distractors' color indeed produces the ignorance of unexpected object, the results from experiment 1 would not be varied by changing distractors' number. Since it is the distractors' color that triggered the inhibition not the number, the subsequent attentional effect should be the same no matter how many distractors there are.

The procedure was identical to previous experiment with the exception that there was only one blue square as the distractor.

1) Participants

35 participants took part in this experiment for monetary rewards, but again two were excluded due to their failures to notice the cross in the full attentional trial. In the end, 33 participants (22 females) were included in the final analysis: Blue Group (7 female, 4 male), Red Group (7 female, 4 male), and Two-Color Group (8 female, 3 male). The average age was 22.24. The age across the three group was not significantly different (F(2,30) = 2.605, p = 0.091).

2) Results

The noticing rate in the critical trial did not differ significantly between three groups (χ^2 = 1.251, p = 0.850). There was also no difference in count error either (F(2,30) = 1.218, p = 0.310). However, for noticer, there was significant difference of count error between three groups (F(2,16) = 10.493, p = 0.001), with blue group showed the highest error(0.62), while the other groups showed lower error (0.25 in Red Group, 0.23 in Two-Color Group). The noticing rate and count error were not significantly different among the three groups in non-critical trials.

3) Discussion

Unlike results in experiment 1, there was no significant difference of noticing between three groups. This seems to refute our hypothesis. However, even the Red Group and Blue Group did not show typical result of IB. If attentional set facilitating attention on targets is the only factor, the noticing should be higher in Red Group than in Blue Group. Therefore, there must be some process other than attentional set in Blue Group, and the process is impaired in the present experimental task. The reducing inhibition of distractor's color may account for the result. Possibly inhibition from only one distractor is not strong enough to prevent seeing of the unexpected object, while inhibition from four distractors can prevent the activation from new object.

Some studies have found the effect of inhibition depend on attentional level [9]. The inhibition occurred after the initial exciting, and depended on the initial level. The higher level of early activation in the distractor is, the deeper it is subsequently inhibited. If distractors are more salient and intrusive, the later inhibitory feedbacks will be more intensive than less salient distractors [14]. According to this explanation, one distractor may produce a low level of activation, so the subsequent inhibition was insignificant. The inhibition in both Blue Group and Two-Color Group is not sufficient to prevent noticing the unexpected object.

The difference of count performance furthermore challenged the theory of pure attentional facilitation. The only one distractor was also processed and then inhibited, so the activation of such features in Blue Group costs more attentional efforts. Attentional resources are needed to override the inhibition, even if the inhibition is still not strong to prevent taking the unexpected object into awareness. Therefore, the different effect on the primary task may be attributed by a subliminal impact of inhibition.

C. *Combined Results of Experiment 1 and 2*

MANOVA with groups and experiments as two independent factors was conducted to compare the results from both experiments. The noticing rate in the critical trial was significant different 1($F(1,79) = 28.608$, $p < 0.001$), with the average rate higher (81.82%) in experiment 2 than in experiment 1 (36.54%). There were no differences in other trials. Count error in the second trial was marginally different between two experiments ($F(1,79) = 3.835$, $p = 0.054$), with 0.16 in Experiment 1 and 0.11 in Experiment 2. However, such difference did not remain in later trials.

To pool the data from both experiments, the Blue Group showed less noticing rate in the critical trial ($F(2, 79) = 7.427$, $p = 0.001$). There was interaction between group and experiment for noticing rate in the critical trial ($F(2,79) = 5.997$, $p = 0.004$). Simple effect analysis found that for Blue Group, noticing rate was higher in experiment 2 than in experiment 1 ($F(1,81) = 22.47$, $p < 0.001$). For Two-Color Group, the difference was also significant ($F(1, 81) = 18.41$, $p < 0.001$).

Fig.2 shows the compared results. The less the distractors, the less possible of IB. This analysis suggests that inhibition may be not all-or-none; it is the level of inhibition that determinate the perception of unexpected object. The number of distractors influences the level of inhibition. In both experiments, noticer in Blue Group showed higher attentional cost. The higher inhibition in Blue Group costs more attentional resources. In summary, the number of distractors affects the inhibitory level, and the inhibition required attentional resources to override, even though it is not strong enough to prevent the to-be-ignored features coming into awareness.

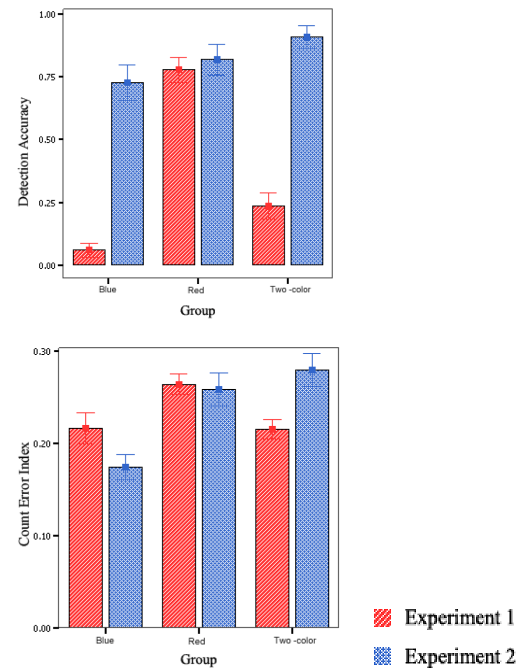


Figure 2. Overall comparison of noticing rate and count error in the critical trial between two experiments.

IV. APPLICATION

The two experiments show inhibition on distractors contributes to inattentional blindness. The inattention model can be highly informative in artificial intelligence. Such model has been implemented in conversational agent to improve the fidelity of virtual communication [15].

Similarly, an aware system need to match the characteristics of human's attention, so that it is capable of supporting human's attentional processes in an appropriate way [16].

Besides, understanding the nature of attention failure is significant to improve awareness of critical information but prevent disturbance from irrelevant interference. It can promote autonomous agents' ability of attentional shift from current focus to other more urgent or important events[17].

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