行政院國家科學委員會補助專題研究計畫成果報告

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計畫主持人：葉素玲

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執行單位：台灣大學心理系

中　華　民　國　　90　年　9　　月　12　　日

行政院國家科學委員會專題研究計畫成果報告

知覺組織與注意力

Perceptual Organization and Attention

計畫編號：NSC 89-2413-H-002-043

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一、中文摘要

對於知覺與注意力的諸多理論，特別是物體為基的選擇注意力理論而言，知覺組織的形成是否需要注意力一直是最重要的議題之一。無論是贊成或反對的陣營，一般都假設完形心理學所提出的各種知覺組織原則不是都需要注意力，就是都不需要注意力。本研究採用不注意即視盲(inattentional blindness)的實驗派典(Mack and Rock, 1998)，並結合可避免記憶與知覺爭議的視錯覺測量方式(Egeth and Moore, 1997)，發現完形組織中的連續律可以不需要注意力，但是方向角的相似律卻需要注意力方能達成。

關鍵詞：知覺組織、注意力、不注意即視盲、相似律、連續律

Abstract

The issue of whether perceptual grouping can be formed without attention is important for many theories of perception and attention, especially for object-based theories of attention. While supports for both sides have been provided, it is commonly assumed that Gestalt principles of grouping are all processed at the same stage, either all can be processed without attention, or all must be formed with the deployment of attention. Here we report evidence against such a unifying view. By adopting a sensitive measure concerning the relationship of grouping and attention, i.e., a measure of visual illusions when the inducing pattern of illusion was unattended (Egeth and Moore, 1997) using the inattentional blindness paradigm (Mack and Rock, 1998), we showed that grouping by continuity can be formed under conditions of inattention, but grouping by orientation similarity alone cannot.

Keywords: perceptual organization, attention, inattentional blindness, law of similarity, law of good continuation

Introduction

Ever since Neisser (1967), the distinction between preattentive and attentive stages in visual information processing has been prevalent for decades in attention research. In order to allocate attention to the target, it is reasonable to postulate a preattentive stage where certain perceptual processing, for example, grouping or parsing of elements in the retinal image, has already been formed for the selection of attention to be based upon, which is particularly important for object-based theories of attention (e.g., Duncan, 1984; Driver & Baylis, 1989; Kahneman, Tresiman, & Gibb, 1992; Lavie & Driver, 1996; Vecera & Farah, 1994). Therefore, the notion that perceptual organization, especially, the Gestalt laws of similarity, proximity, good continuation, closure, common fate, etc., should be processed preattentively seems logically sound, and empirical evidence has been provided to support for such a preattentive view of perceptual organization (e.g., Beck, 1982; Driver, Balyis & Rafal, 1992; Grossberg, Migolla, & Ross, 1994; Julesz, 1981; Mattingley, Davis & Driver, 1997; Pomerantz, & Schwaitzberg, 1975; Treisman, 1982).

Challenges arise, however, when several lines of evidence demonstrated that attention is required for perceptual organization to be formed. For example, Ben-Av, Sagi and Braun (1992) showed that perceptual grouping by proximity and shape similarity was impaired when the participants had to perform a concurrent demanding identification task, compared to when performing perceptual grouping alone. Similarly, Joseph, Chun and Nakayama (1997) demonstrated that the detection of an orientation singleton was impaired in a dual-task condition than when conducting the detection task alone, which challenges the conventional notion that search for a specific feature does not require attention, as the term “pop out” is usually used to describe the process of feature search. Most critically, Mack, Tang, Tuma, Kahn & Rock (1992) showed that, by using an inattentional blindness (IB) paradigm, perceptual organization such as proximity and similarity of luminance could not be detected when the participants had no expectation and attention to the grouping elements. These results are consistent with an alternative view that not much perceptual process has been accomplished before the deployment of attention, at best location, color, and number of the stimulus (Rock, Linnett, Grant & Mack, 1992). According to this view, perceptual organization is, particularly, not one of the preattentive processing, since it has been shown to be based upon certain, presumably occurring late, perceived properties, rather than on the retinal properties (Rock, Nijhawan, Palmer, & Tudor, 1992; Palmer, 1996; Rock & Brosgole, 1964).

While the issue of whether perceptual organization can be processed without attention is important for many theories of perception and

attention, it is often assumed that the answer is either *yes* or *no*. That is, the Gestalt laws of grouping, such as laws of similarity, proximity, good continuation, common fate and closure, though each may have different strength so that one may overcome the other when they are conflictive (Palmer & Rock, 1994), they are usually considered to be all processed at the same stage, either *with* attention, or *without* attention. Here we provide evidence to the contrary, demonstrating that while one can be processed without attention, the other requires attention.

We were particularly interested in the law of good continuation (continuity hereafter) that has been intensively studied in vision research in the past decade (e.g., Field, Hess and Hayes, 1993; Polat & Sagi, 1993, 1994a, b; Chen, 1999), which can be considered as the revival of Gestalt principles of grouping in the modern theories of vision and perception after being "in a state of suspended animation for more than 60 years" (quotation from Palmer and Rock, 1994, p.30). Though not explicitly stated, it is usually assumed that continuity is processed automatically; that is, if the orientations of local elements are aligned with the orientation of the global path, such a global path seems to "pop out" (Kovacs & Julesz,1994), though it may also be subject to the modulation of attention (Ito, Westheimer & Gilbert, 1998). As horizontal connections among cells in V1 are proposed as the underlying mechanism for the better performance when the elements were embedded in the continuous global path than when standing alone, it seems reasonable to propose that such a "contextual effect" should occur preattentively.

As local elements that appear continuous are also similar in various properties, for example, when the global path is a straight line, all the orientations of the local elements would then be the same, controversies exist about whether similarity of orientation is also as effective as the law of continuity. When attentional status is controlled, however, the results concerning the processing stage of grouping by similarity are inconclusive (Ben-Av, Sagi & Braun, 1992; Mack et al., 1992; Moore & Egeth, 1997). It is thus interesting to examine the two laws (continuity and similarity) within the same experimental framework, since different grouping laws may be processed at different levels.

General Method

To use as sensitive as the measure it can be concerning the relationship of perceptual organization and attention, we modified the IB paradigm in Mack et al. (1992) and the on-line measure of the effect of grouping by visual illusions in Moore and Egeth (1997). We consider this the most sensitive measure for two reasons. First, as Mack and Rock (1998) argued, evidence supports for the preattentive processing of perceptual organization mainly comes from results of visual search and texture segregation, in which participants specifically look for something, be it a target, an odd item, or a discontinuous boundary. Therefore, either evidence for or against the existence of perceptual organization under these conditions tackles, at best, questions of perception under divided or distributed attention. Although this may be conventionally thought to be preattentive, the IB paradigm makes conditions of "inattention" more explicit (Mack et al, 1992; Rock, Linnett, Grant & Mack, 1992, Mack & Rock, 1998), since in the inattetnional trial participants do not expect to be asked about questions other than the primary task, which they are supposed to have devoted full attention to it.

Second, as Moore and Egeth (1997) pointed out, a major problem with the IB paradigm of Mack et al. (1992) is that it depends on subjective report of participants after each trial, which makes memory failure also a possible explanation of the participants' inability to report the background pattern in the inattention trials (see also Wolfe, 1999). To avoid this memory problem, Moore and Egeth (1997) cleverly designed a paradigm to measure the perception concurrently during the inattention trial. In their experiments, the primary task was to judge which of the two horizontal lines that were superimposed on the background was longer. In the inattention trial, the background dots could be grouped by the black dots (segregated from the other white dots) to form the two tracks in the railroad-track (Ponzo) illusion. If grouping does occur and so the two tracks can be perceived as seen in the Ponzo illusion, the line that is adjacent to the converging end of the two tracks should be perceived as longer than the one that is nearby the diverging end. It was indeed found to be the case (Moore & Egeth, 1997). Although the percentage of oral report was also quite low in the inattentional trial, consistent with Mack et.al, the line-length judgment was significantly biased by the illusion. This was taken as an evidence showing that without attention, grouping by similarity of luminance (black vs. white dots), though could not be reported as in Mack et al (1992), could, nevertheless, be perceived and demonstrated in visual illusions. Therefore, by putting the inducing pattern in the unattended background, an on-line effect of grouping could be more sensitively measured under conditions of inattention.

In the IB task adopted here, we took advantage of the virtue and yet avoided several confoundings of the above two studies. The participants were first told to judge which of the two horizontal lines was longer. A background pattern contained the two railroad tracks as in the Ponzo illusion was presented unexpectedly in the inattention trial after 15 trials of the single line-length judgment task, thus the participants have no prediction or attention to the background when it first appeared in the 16^{th} trial. The illusion background was also presented in the next (17^{th}) trial, but since the participants had had already expectance of it, the detection of it was thus under the conditions of divided attention. In the last (18^{th}) trial, the participant was asked, once again, only a single

task, but this time to report the background pattern while ignoring the original line-length judgment task. Performance in such a focal attention condition was used as the visibility control of the background pattern.

Two kinds of measure were made during the last three critical trials. The first one was the report of the background pattern, as in Mack et al. (1992), and the second was the bias in the line-length judgment task, as in Moore and Egeth (1997). The two lines in the three critical trials were always of the same length, but participants were required to make a forced choice as to the relative length of the two lines. The background pattern either formed an upward railroad or a downward one, and the chance of each was equally distributed across participants.

The first 15 trials were served as the baseline control of the line-length judgment task, in which the two lines were embedded in a random background that no meaningful patterns could be formed. Among these, six trials contained two lines of unequal length chosen from one of the four pairs: (3.2°, 3.4°), (3.4°, 3.6°), (3.6°, 3.8°), (3.8°, 4.1°). Another nine trials contained two lines of equal length. The presentation order of these 15 trails were randomly mixed.

Two improvements were made in this study compared to that in Moore and Egeth (1997). First, 16 trials with the illusion background were presented before the three critical trials in Moore and Egeth (1997), which might have primed the participants the existence of the background pattern. In our study, the illusion background was presented only and for the first time in the inattention trial to avoid the possible priming effect from previous trials before the critical ones appeared (cf., Rock et al., 1992). Second, the black and white dots in the background of Moore and Egeth (1997) created the first-order signal available to the low spatial frequency filters, thus not necessarily evoking perceptual organization. Any blurring effect, either caused by low spatial resolution of the peripheral vision or squinting eyes by the participants, as acknowledged by them (Moore & Egeth, 1997, p. 347), would make the two railroad tracks in the Ponzo illusion appear as two continuous lines. Therefore, in this study we used stimuli that could be detected only through second-order local association among filters, the Gabor patches, that can be viewed as representing the receptive fields of V1 cells that tuned to different orientations (DeValois & DeValois, 1988).

Our background field was thus consisted of 225 Gabors, subtended about 11.9° ×11.9° of visual angle from a viewing distance of 67 cm. A single Gabor was about 0.70° of visual angle, with spatial frequency of 6 cycles/degree in 100% contrast. For the non-pattern background in the first 15 trials, the locations and orientations of the Gabors were randomized, with the constraint that none of the Gabors was overlapped with another, as seen in Figure 1D. For the illusion background in the last 3 trials, 26 Gabors formed 2 inducing tracks as in the Ponzo illusion. The orientation of the Gabors was aligned with the orientation of the global paths of the Ponzo illusion in Experiment 1 for testing the law of continuity (Figure 1A), or it was 90° in Experiment 2 (Figure 1B) and 0° in Experiment 3 (Figure 1C) for testing the law of similarity. Each of the two tracks in the Ponzo illusion subtended 10.8° of visual angle, with the nearest separation being 1.5° and the farthest 5.8°.

The participants were 62 undergraduates at National Taiwan University, with 22 participated in Experiment 1, 20 in Experiment 2, and 20 in Experiment 3. Assurance had been made in each experiment that none had participated in any IB experiments or had known the purpose of these experiments before.

Stimuli were displayed on an Eizo FlexScan T662-T monitor and controlled by an IBM compatible personal computer with a Visual Stimulus Generator card (VSG2/3F, Cambridge Research System). Each trial began with a fixation point on the center of the screen for 600ms, followed by the display containing two grey horizontal lines embedded in the background for 500ms in Experiment 1 and 1000ms in Experiments 2 and 3. Then the display turned blank until the experimenter reinitiated the next trial. At this time, the participant was asked to report verbally which of the two lines appeared longer. If they were not certain about the answer, they were encouraged to guess.

After the participants had completed the 16th trial (the inattention trial), they were asked for the first time the question concerning the pattern appeared in the background: "Did you see any pattern in the background in the last trial?" If the participants did not know the answer, they were encouraged to guess. Participants were asked this question again after they made the length judgment in the 17th trial (the divided-attention trial). Before the last trial (the focal-attention trial) began, the participants were told to ignore the line-length judgment task and to report any meaningful pattern seen in the background of the 18th trial.

Results

Experiment 1

For the first 15 control trials, the mean percent correct of the line-length judgment in the different-length trials was 96.21%. In the same-length trials, the mean percent for electing the top line as longer was 53.03%; for selecting the bottom was 46.96%, no significant bias occurred.

For the last 3 critical trials, the mean percentage of reporting the pattern in the background in the inattention, divided-attention and focal-attention trials was 9.1%, 59.1% and 90.0%, respectively. This is consistent with Mack et al.(1992) in that participants could not report having seen the two tracks in the Ponzo illusion under conditions of inattention. In the inattention and divided-attention trials, however, the mean percentage of judging the line lengths of the two horizontal lines in correspondence with the direction of Ponzo illusion was 77.3% and 81.8%, respectively,

both was significantly higher than the change level. These results showed that although very few participants could report what they saw in the background in the inattention trials, their judgments of the lines were actually influenced by the background pattern, as demonstrated by the Ponzo illusion they exhibited. Therefore, the local elements in the background must have been grouped according to the law of continuity in order for them to be perceived as the two tracks in the Ponzo illusion.

Experiment 2

The display duration was increased to 1000ms in this experiment for the reason that a pilot experiment showed that none of the participants could see the background pattern formed by orientation similarity for the duration of 500ms even under conditions of focal attention. The time difference between continuity and similarity may thus also reflect different processing stages of these two laws.

For the first 15 control trials, the mean percent correct of the line-length judgment was 98.3% in the different-length trials. In the same-length trials, the mean percentage for electing the top line as longer was 52.2%; for selecting the bottom was 47.8%, no significant bias occurred. For the last 3 critical trials, the mean percentages of report seeing the background pattern in the inattention, divided-attention and focal-attention trials was 0% ,10.0% and 55.0% , respectively. In the inattention and divided-attention trials, the mean percentage of judging the line length in correspondence with the direction of Ponzo illusion was 40.0% and 60.0%, respectively, no significant bias occurred, either. This indicates that the local elements in the pattern background, though all are oriented the same, 90°, could not be grouped by their similarity in orientation to yield the two inducing tracks in the Ponzo illusion.

Experiment 3

For the first 15 control trials, the mean percent correct of the line-length judgment was 97.5% in the different length trials. In the same length trials, the mean percent for electing the top line as longer was 54.4%; for selecting bottom was 45.6%, no bias occurred.

For the last 3 critical trials, the mean percent of reporting the background pattern in the inattention, divided-attention and focal-attention trials was 0 % ,30.0% and 65.0% , respectively. In the inattention and divided-attention trials, the mean percentage of judging the line length according to the direction of Ponzo illusion was 45.0% and 65.0%, respectively. No significant bias occurred. These data showed that participants were not influenced by the background pattern, in which the local elements needed to be grouped by their similarity in orientation (all are 0°) in order to be perceived as the two tracks in the Ponzo illusion.

General Discussion

In Experiment 1, grouping by continuity could be formed under conditions of inattention to render the Ponze illusion as measured by the bias in the line-length judgment. Grouping by orientation similarity alone, however, could not be formed without attention, as demonstrated in Experiments 2 and 3. The failure to find grouping by similarity should not be attributed to orientations used in this study, since vertical and horizontal are the two orientations that people are most sensitive to. It may be criticized that the local elements in the background pattern of Experiment 1 also shared the same orientation; though a tilted, less salient one, it is still possible that similarity of orientation also exerted its effect there. The lack of grouping by similarity alone in Experiments 2 and 3, however, argues against the idea of preattentive processing of orientation similarity alone. The effect of continuity may be stronger when combined with similar orientations of the local elements, as many patterns seen in natural environments. The main point here is, however, grouping by continuity can be formed without attention, while grouping by orientation similarity alone cannot.

Such a finding thus indicated that continuity and similarity were processed at different stages, with the former earlier than the latter. The finding of preattentive processing of continuity, defined as the orientations of the local elements aligned with their global path, provides new evidence that is in accordance with the implicit assumption of many of the psychophysical and physiological studies concerning the contextual effect. Although it has been shown that continuity can be modulated by attention (Ito & Gilbert, 1999; Ito, Westheimer, & Gilbert, 1998), such attentional modulation should not, on logical grounds, exclude the possibility of preattentive processing of continuity.

The lack of grouping by similarity without attention is consistent with Mack et al. (1992), but at odds with Moore and Egeth (1997), although we adopted a more sensitive measure of the latter. Four possible reasons can be provided to account for the discrepancies. First, the repetitive exposure of the background pattern presented before the critical trials as in Moore and Egeth (1997) may have helped grouping by similarity to be primed. When such priming did not exist as in our study, grouping by similarity failed. Nevertheless, continuity survives under the same manipulations.

Second, the findings of grouping by similarity in Moore and Egeth (1997) may be due to the stimuli they used, which did not actually invoke perceptual organization. When carefully controlled for the stimuli to exclude the possibility of the contribution from the first-order low-spatial-frequency filters, as done in this study, the effect of similarity disappeared.

Third, and a major problem with the black and white dots used in Moore and Egeth (1997) was that,

single dots contained all kinds of orientations, so that the positive finding of similarity in Moore and Egeth (1997) may simply result from grouping by continuity, as in our Experiment 1, rather than similarity. Figure 3 illustrates this point. Thus, a caveat here. The law of similarity, when stated, should be cautious to differentiate its various forms. When single dots as most demonstrations of Gestalt laws have used, what really contributes the perceptual grouping should be specified with more elaborated considerations.

Finally, the grouping elements in the background display in Moore and Egeth (1997) was more salient than that in our study. This is indicated by the fact that all the display durations used here were longer than that in Moore and Egeth (1997), 200ms. Grouping by similarity was not possible even under durations of 1 sec in Experiments 2 and 3. The salience of the stimulus thus seems to affect the ease of perceptual organization. However, the same less salient elements were, nonetheless, easier to be grouped by continuity as shown in Experiment 1. The term "salience" thus should be more elaborated as well. The effect of salience, again, may be caused by the effect of continuity, which is in turn due to various orientations that the dots contained, rather than due to the luminance contrast of the black and white dots.

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Figure Legends

Figure 1. The background pattern in the last three critical trials in Experiment 1(A), Experiment 2(B), Experiment 3(C), and the non-pattern background for the three experiments (D).

Figure 2. (A) Percentage of reporting seen background pattern (two railroad paths) in the 3 experiments for the three critical trials. (B) Percentage of length judgment influenced by Ponzo illusion under conditions of inattention and divided attention.

Figure 3. Single dots contained all kinds of orientations and thus grouping by similarity of luminance (black vs. white) (A) may be caused by grouping by continuity (B).

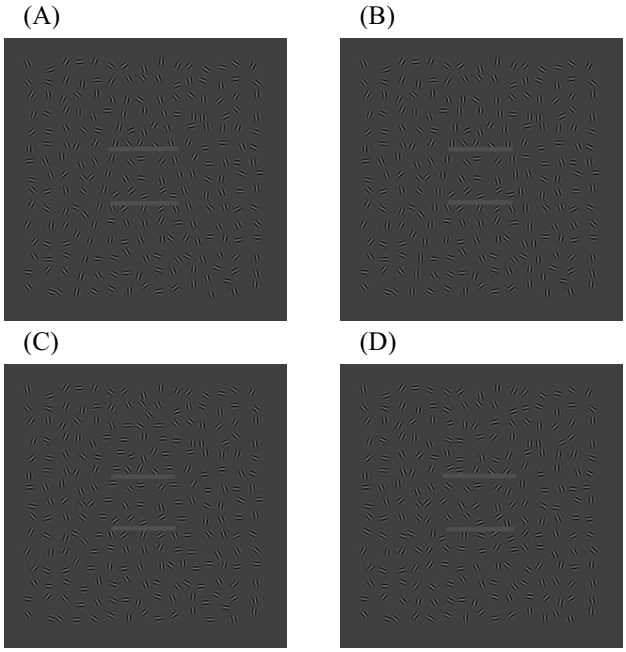

Figure 1

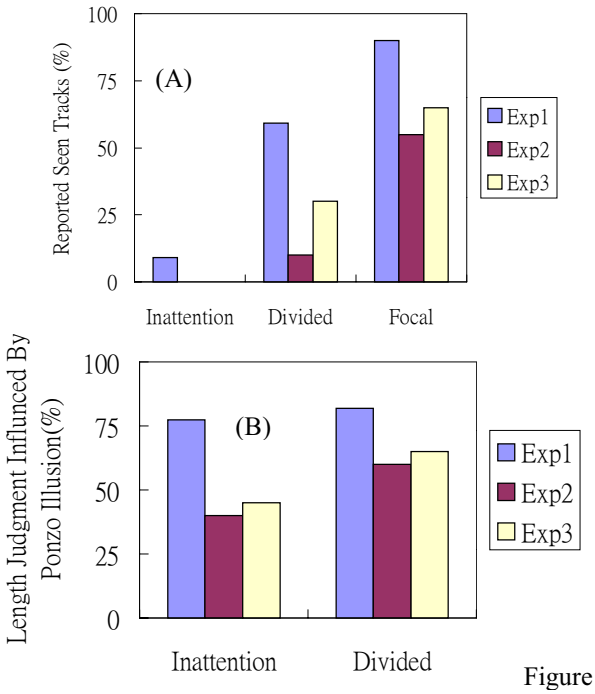

Figure 2

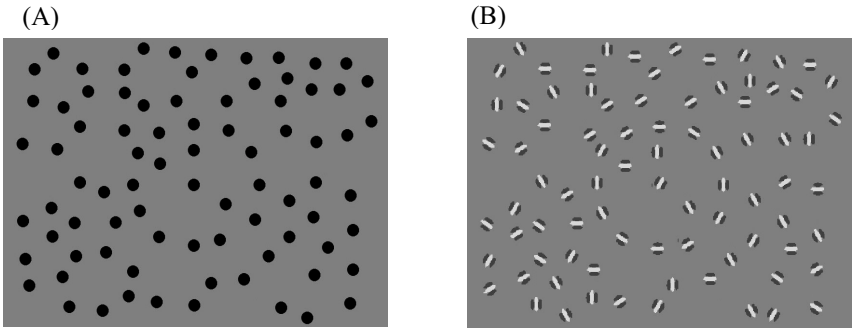

Figure 3