Perceptual learning of dot pattern

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Abstract Dot pattern is a type of pattern defined by specific spatial relationship among some dots. As a compensation for concrete and meaningful visual stimuli, meaningless dot pattern can be used as stimuli in learning tasks. We performed an experiment for exploring the perceptual learning process of dot pattern against random-dot background. Participants were required to learn two types of dot patterns (9-dot and 11-dot). They were assigned to two groups: participants in Group 1 learned 9-dot pattern first and 11-dot pattern later, while those in Group 2 learned 11-dot pattern first and 9-dot pattern later. The results showed that participants could acquire the spatial relationship of dot pattern through perceptual learning in relatively short learning time. In comparison with 9-dot pattern, learning time of 11-dot pattern was slightly longer and its accuracy rate lower, but there was significant positive transfer effect from 11-dot pattern learning to 9-dot learning.

Keywords: perceptual learning, dot pattern, transfer, sequence effect.

Plenty of studies proved that perceptual learning exists in various visual tasks, such as stereogram[1], gratings detection[2], hyperacuity[3], motion detection[4], texture discrimination[5], visual search[6] and pattern recognition. Some studies also showed that perceptual learning involved orientation identification[1,3,6] and localization in the eye field[7]. According to La Berge, as the connection of less familiar stimuli got strengthened, its most ostensible parts turned out to be a separate functional unit[8].

This research was inspired by the following question: Was it a result of perceptual learning when the ancient people classified the constellation? From the authors' observation, it is easier to identify constellation as the observation time increases. It can be inferred that perceptual learning took place in the above process. In this paper, the learning material composed by some dots (correspond to stars in a constellation), named as dot pattern is introduced. It is different from the traditional visual stimuli that are concrete and meaningful, but it does have a type of spatial relationship among dots. As Ahissar suggested[9], perceptual learning could be divided into three different levels: stimulus feature, feature combination and text recalling. Perceptual learning of dot pattern does not belong to any level above, since it has no feature, no feature combination or textual meaning. This research is intended to examine this new type of perceptual learning.

Dot pattern learning has three special characteristics. First, the dots forming a pattern are identical in shape, in color, and in size to random dots in background, so background variation plays a key role in learning. Second, though a dot pattern is against an unstable background, each random dot has a chance of 5/6 to occur at a different position while 1/6 to remain at the original position in the following picture, preventing "pop-out effect"[10] due to illusion of movement. Third, because the dot patterns to be learned are meaningless and have not been presented separately throughout the whole course of experiment, top-down or bottom-up processing alone cannot explain this type of learning. The goal of this research is to examine the feasibility and the transfer effect of perceptual learning of dot pattern.

In this research, both the target stimuli and non-target stimuli were pictures composed of black dots identical in shape, in color, and in size (Fig. 1). During the phase of picture learning, participants were required to differentiate a target dot pattern on a fixed location from its random-dot background. To test the learning effect, participants were then asked to judge whether test pictures contained the target dot pattern or not. The random dots provided a homogeneous background with dot pattern, hence past experience was controlled and the interference of contextual cues was ruled out. So it could be safely inferred that improvement in the test scores could be regarded as improvement in the ability of dot-pattern recognition.

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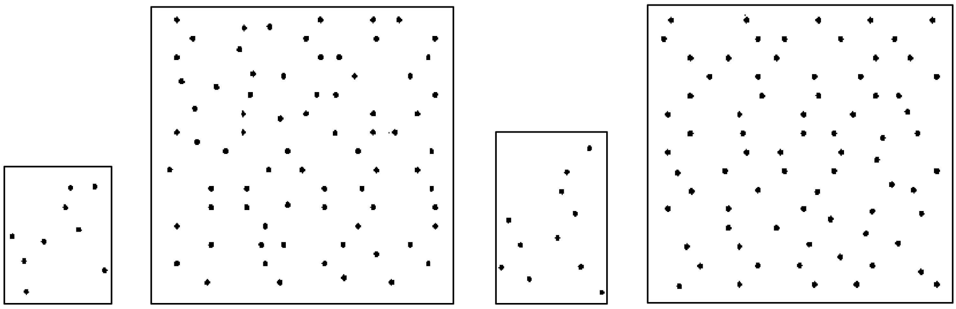

(a) (b) (c) (d)

Fig. 1. Learning materials of dot pattern, among which (a) is a 9-dot pattern; (b) is a dot picture containing (a); (c) is an 11-dot pattern and (d) is a picture containing (c).

1 Method

1.1 Participants

Thirty-four undergraduate students (15 males and 19 females) with normal or corrected-to-normal vision from East China Normal University took part in the experiment.

1.2 Stimuli

A learning item was a picture combined by a random-dot background (500×500 pixel) and a dot pattern containing 9 or 11 dots.

A series of random-dot background pictures was generated with custom software written in Visual Basic. Each random-dot background was divided into 25 squares, with 3 black dots (each with the size of 9 pixels) randomly located in each square. Therefore, there were 75 identical black dots in a random-dot background altogether.

Dot patterns were generated by the following procedure. First, six 9-dot patterns were created. Each dot in a pattern had a relative spatial position. Second, 5 undergraduate students were required to imagine the "meaning" of these dot patterns. A 9-dot pattern with the lowest consistency in association (the most meaningless) and lowest difficulty was selected to be stimulus prototype in the experiment (Fig. 1 (a)). Third, an 11-dot pattern (Fig. 1(c)) was generated based on the 9-dot pattern, among which 5 dots were kept in their original position, 2 dots were slightly moved to avoid recall effect overwhelming the transfer effect, 2 dots were erased and other 4 dots were added.

Fig. 1(a) and 1(c) are the 9-dot and 11-dot patterns to be learned, respectively; Fig. 1(b) and 1(d) are combination of a dot pattern and a random-dot background, respectively. The combination procedure was as follows: first a dot pattern and a random-dot background were selected, then the dot pattern was pasted on background and the random dots closest to the pattern dots were erased to keep the total number of dots unchanged. Meanwhile, some random-dot pictures without dot pattern were also generated for testing phase.

1.3 Procedure

Stimulus presentation and response recording were performed with another custom software written in Visual Basic running on a PC linked to a 15 in. CRT monitor in 800×600 resolution mode. The size of each dot picture was $17^\circ \times 17^\circ$ with each dot $0.27^\circ \times 0.27^\circ$. The learning procedure of this experiment was "learning—testing—learning—testing—learning …" until the participants learned the dot patterns.

Learning phase: 30 pictures with one of the dot patterns were presented. Each picture was presented for 5 seconds. Participants were required to differentiate the target dot pattern from its random-dot background.

Testing phase: after presenting one block of 30 pictures, 5 testing pictures were presented, among which the ratio between the pictures with or without target dot pattern was 2:3 or 3:2. For each picture, the participants were required to decide whether it contained the dot pattern in the previous learning phase or not. Participant's learning was defined to be successful if he or she classified 5 successive pictures correctly (the probability of correct guessing is $0.5^5 = 0.03125 < 0.05$, so 5-correct-answer can be regarded as successful learning).

If participants failed in testing phase, another learning phase began. Procedure would stop after 8 blocks of learning—testing.

In order to examine sequence effect in the perceptual learning of dot pattern, participants were assigned to two groups. Group 1 learned the 9-dot pattern first and 11-dot pattern later, while Group 2 learned the 11-dot pattern first and 9-dot later.

2 Results

2.1 Average learning time and accuracy rate

We calculated time for successful learning and accuracy rates. Accuracy rate = 1 − (number of errors/number of identifications). Table 1 shows the average learning time and accuracy rates for the two types of dot patterns. Twenty-nine out of 34 participants successfully learned the dot patterns, indicating that dot pattern learning was an appropriate and valuable task of perceptual learning.

The learning time of 11-dot pattern was slightly longer and its accuracy rate was a little bit lower than those of 9-dot pattern, but there was no statistically significant difference: t-test for accuracy rate shows $t = 1.168$, $p > 0.05$.

Table 1. Average learning time and accuracy rates for the two types of patterns

Type	Learning time (s)	Accuracy rate	Standard deviation of accuracy rate
9-dot pattern	296	0.87	0.21
11-dot pattern	389	0.81	0.18

2.2 Transfer effect of two learning orders

There were two types of learning order—9-dot pattern first and 11-dot later (Group 1 or Order 1, in which 13 participants successfully learned dot patterns), and 11-dot pattern first and 9-dot later (Group 2 or Order 2, in which 16 participants successfully learned dot patterns). The learning time and accuracy rates for the two orders are shown in Table 2. The learning time for the same dot pattern was longer in the first task than the second one, indicating that the pre-learned dot pattern had positive transfer effect on the post-learned dot pattern. The t-test of accuracy rates showed a sequence effect. There was a significant transfer effect by 11-dot learning on 9-dot learning, $t = 2.632$, $df = 15$, $p = 0.009 < 0.01$, while transfer effect by 9-dot on 11-dot was of no significance, $t = 0.1236$, $df = 12$, $p = 0.904$.

Table 2. Transfer effects in dot pattern learning

	Order 1		Order 2	
	9-dot pattern	11-dot pattern	11-dot pattern	9-dot pattern
Learning time (s)	312	381	395	282
Accuracy rate	0.84	0.85	0.82	0.93

3 Discussion

Results show that dot patterns could be learned in relatively short time. Because each dot was located independently, dot patterns had no obvious contour or other features. Dot patterns in this experiment were meaningless, so this type of perceptual learning should require both top-down and bottom-up processing. In Gibson's opinion, perceptual learning dissociated the characteristics of invariability and differentiation in stimuli. When a person attempted to solve the problem of the uncertainty in perception caused by novel stimuli, he/she spontaneously differentiated the characteristics of stimuli. Gibson proposed two mechanisms for identification improvement: differentiation and enrichment. Differentiation discards unrelated information, inputting or enhancing the important information, while enrichment strengthens information that has more connection at the very beginning of learning[11].

The mechanisms of enrichment and differentiation seem to antagonize with each other. The most obvious contradiction was that perceptual learning created a big chunk after enrichment, while the stimuli were divided into different, specific and small parts. Generally speaking, two mechanisms depended on the features of tasks and stimuli. If components of stimulus reflected independent sources of variance (i.e., components were totally different), stimulus tended to be divided into different dimensions. But if components occurred simultaneously (i.e., all components showed similar reaction), they tended to combine. The eventual purpose of these two mechanisms was to construct an appropriate representation. The learning process of dot pattern might be a result of cooperation between differentiation and enrichment mechanism. Differentiation occurred due to the different attributes of target dots and random background dots, and enrichment was a product of the fixed pattern within target dots.

The positive transfer effect from 11-dot pattern to 9-dot pattern showed that the learning for a dot pattern with wide range could facilitate the learning for a narrower pattern. Because there was no statistically significant difference in learning time and accuracy rates between 9-dot and 11-dot pattern, transfer effect might not be influenced by difficulty of dot patterns. Therefore, it could be inferred that after learning a pattern with more dots, it is likely for participants to enlarge their searching range and strengthen their integration of spatial relationship in the following learning. Otherwise, the integration might be impaired.

4 Conclusion

This research examined the feasibility of dot pattern perceptual learning and its transfer effect. Results showed that dot pattern could be used in perceptual learning task. Furthermore, there was positive transfer effect in the dot pattern learning, and 11-dot pattern had stronger transfer effect on 9-dot pattern.

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