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A study on sampling strategies in the figure cognitive process*

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Abstract: This study was aimed at investigating the sampling strategies for 2 types of figures: 3-D cubes and human faces. The research was focused on: (a) from where the sampling process started; (b) in what order the figures' features were sampled. The study consisted of 2 experiments: (a) sampling strategies for 3-D cubes; (b) sampling strategies for human faces. The results showed that: (a), for 3-D cubes, the first sampling was mostly located at the outline parts, rarely at the center part; while for human faces, the first sampling was mostly located at the hair and outline parts, rarely at the mouth or cheek parts, in most cases, the first sampling-position had no significant effects on cognitive performance and that (b), the sampling order, both for 3-D cubes and for human faces, was determined by the degree of difference among the sampled-features.

Key words: Sampling strategy, Figure cognition, 3-D cubes figures, Human faces
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INTRODUCTION

The first step of figures cognition is sampling. During the process of sampling, what kinds of information are sampled? And in what order the figure features are sampled? These 2 problems are the main issues in the sampling strategy in figures cognitive process.

Lindsay and Norman (1977) believed that in people's memory there were some templates which could match anything in the world. When people saw an object, some information from the retina was compared with the templates in the mind, if their similarity exceeded a certain threshold, then the object was recognized. Lindsay called this theory "template matching model". Selfridge and Neisser (1960) believed that the cognitive process was like an inverted tree. On every processing level were some demons responsible for their feature-concentrated process, so Selfridge called his theory "Pandemonium". Marr (1982) proposed a computational model to explain vision. Marr believed objects could be represented in 2 ways: observer-center way or object-center way. Marr believed object-center was better because it was more stable. Massaro and Cowan (1993), Townsend *et al.*(1980), Shibuya and Bundesen (1988) hypothesized sampling behavior existed during the cognitive procedure. Based on this hypothesis, Busy and Loftus (1994) raised their "Independent sampling process" theory. The key idea of the theory was that every sampling behavior was independent of each other in logic. Guez *et al.*(1994) proposed the 2-stage process model. At the first stage, the attention spot-light focused on some gravity centers of

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angle parts; then at the second stage, the fovea vision concentrated on the gravity center doing sampling. Vecera and O'Reilly (2000) proposed an interactive model, which emphasized that both concept-level cues and stimulus-level cues had the same importance in pattern activations. Baylis and Cale (2001) found that the figural priming effect was due to residual activation of figural shape. The nonfigural shape was not processed, as it had none of that residual activation.

Based on the studies mentioned above, we could sum up: figure was a very special visual material containing a great deal of information. Sampling from figures was an exploratory process; there was a lot of information for observer to discover, and the relations among information pieces were unstable and needed to be organized by observers. The cubes and human face were 2 typical kinds of figures, so we chose them as the stimuli materials in this study.

EXPERIMENT 1: COGNITIVE STRATEGIES FOR SAMPLING 3-D CUBES FIGURES

Experiment 1 was designed to investigate the sampling strategy for 3-D cubes figures.

Method

Subjects: sixty-four college students, 34 males and 30 females, participated in this experiment. All subjects had normal color vision and normal or corrected normal vision.

Apparatus: The experiment was conducted using an IBM PII computer with 15-inch monitor. The stimulus displayed on the center part of the monitor with size 289×289 pixel (about 10.2×10.2 cm). The distance from the stimulus to the subject's eye was 50 cm, approaching to 11.4° vision angle. The experiment was programmed in DELPHI 5.0 language.

Stimuli: The stimuli of the experiment were 20 3-D cubes (shown in Fig.1).

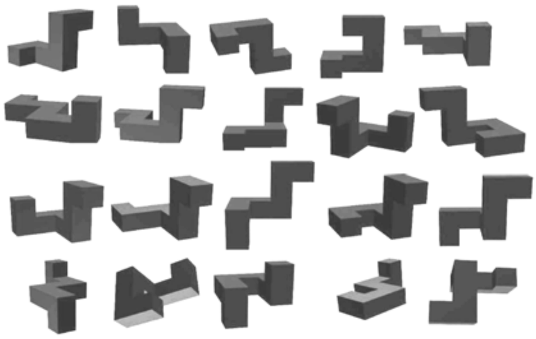

Fig.1 3-D cubes used in Experiment 1

Design: 2×2×2 mixed factorial design was used in Experiment 1. The 3 independent variables were: (1) 2 visual tasks (between-subject design): a) confirming task, 2 figures were presented on the monitor screen; then subjects were required to judge if the 2 figures were the same or not; b) matching task, a target was presented on the monitor first, then 4 figures were presented later. Subjects were required to judge which one was the target. (2) 2 display conditions (between-subject design): a) clear display condition, the target-background contrast was 27.8:1; b) ambiguous display condition, the target-background contrast was 0.07:1. (3) 2 display manners (within subjects design): a) rotated display, targets rotated in different degrees first, then presented on the screen, whereas the matching figures kept their original positions. The rotation degrees were 0°, 30°, 60°, 90°, 120°, 150°, 180°, 210°, 240°, 270°, 300°, 330° respectively; b) not-rotated display, the target kept 0° rotation degree.

The response time (RT) was recorded as the dependent variable.

Questionnaire: A questionnaire was used to collect information about the sampling strategy, and the questionnaire was made by a pilot experiment.

Procedure: The experiment consisted of two tasks, different tasks with different procedure. (1) Confirming task: subject pressed the "Begin" button, with a sound "dong", a 3-D cube (target) was displayed at the center of the screen for 100 ms; then a 2-second-long time interval; after that the second figure would be displayed (maybe rotated some degrees). The subject was required to press the mouse button as soon as he identified the 2 figures were the same or not. With the button was pressed, the figure immediately disappeared and a response window popped out. In the window there were 2 buttons labeled "Yes" and "No" respectively. The subject should press one of them as response. The 20 figures were presented in random order, and the probability for the same cases was 0.5. In the end, subjects were required to fill in a questionnaire on sampling strategy. (2) The matching task: the procedure was similar to that of the confirming task, the difference was that the second figure was made up of 4 3-D cubes and the answer window had 4 buttons with the same configuration. The subject was asked to press one button in response as to the position that the target located at.

Results

The first sampling parts: The results from the questionnaire are shown in Table 1.

It clearly showed that most subjects chose "outline" (49.2%) as the first sampling parts, then, "some cube" (13.3%) and "some direction" (11.7%). Only very few subjects chose center (4.7%) or "no idea" (3.9%) as the first sampling parts. The result of χ^2 test indicated that the first sampled parts were significantly not uniformly distributed (χ^2=133.7, P<0.01); which indicated that for the 3-D cubes, subjects sampled information mostly from the outline or some cube parts, rarely from the center parts.

Effect of first sampling on visual performance: The results of ANOVA showed that in most cases the first sampling had little effect on visual performance (P>0.05).

Sampling order: The sampling order is shown in Table 2. Both Friedman and Kendall test indicated that the sampling order was significantly not random (P<0.01); which suggested that subjects had order arranged similarly as shown in Table 2.

In a pilot experiment, we scaled the differences degree of the 12 features in the 20 stimuli figures. The correlations between the rank of the 12 features (from the pilot experiment) and the ranks of the sampling order (from this experiment) varied from 0.815 to 0.871 (depended on different experiment conditions), but all the correlations were statistically significant (P<0.01). The results showed that the sampling order was consistent with the difference degree of the features, and suggested that features with higher difference degree be sampled

Table 1 Frequency and percentage of first sampling parts (3-D cubes)

	Outline	Center	Some cube	Some direction	Some face	Random	No idea	χ^2	P
Frequency	63	6	17	15	11	11	5	133.7	0.000
Percentage	49.2	4.7	13.3	11.7	8.6	8.6	3.9		

Table 2 Sampling order in different condition (3-D cubes)

		12 features												χ^2	W	
		Outline	Structure	Key	Angle	Center	Combination	Margin	Direction	Surface	Volume	Number of cube	Meaning	Friedman test	Kendall's co-efficient	P
Task	Confirm	2.94	3.39	4.97	5.30	7.17	6.75	6.89	6.81	7.38	7.64	8.41	10.36	233.90	0.332	0.00
	Match	3.69	4.11	3.50	5.47	6.39	6.81	6.80	7.34	7.22	8.39	9.22	9.06	219.96	0.298	0.00
Display manner	Rotated	3.58	4.20	4.25	5.45	6.66	6.66	6.63	6.91	7.31	8.30	8.31	9.75	186.77	0.265	0.00
	No-rotated	3.05	3.30	4.22	5.31	6.91	6.91	7.06	7.25	7.28	7.73	9.31	9.67	246.71	0.350	0.00
Display condition	Clear	3.44	3.58	4.20	5.31	6.52	7.30	7.03	7.70	7.03	8.05	8.70	9.14	204.15	0.290	0.00
	Ambiguous	3.19	3.92	4.27	5.45	7.04	6.26	6.66	6.45	7.56	7.98	8.92	10.28	234.26	0.333	0.00
	Average	3.31	3.75	4.23	5.38	6.28	6.78	6.84	7.08	7.30	8.02	8.81	9.71	426.38	0.303	0.00
	Z score	1.43	1.34	1.18	0.79	0.71	0.09	−0.28	−0.41	−0.56	−1.03	−1.12	−1.50			

prior to those with lower difference degree.

EXPERIMENT 2: COGNITIVE STRATEGY FOR SAMPLING HUMAN FACE FIGURES

The human face is a kind of very specific figure. Research on face recognition has great practical value for human beings.

Method

Subjects: sixty-four college students, 31 males and 33 females, participated in this experiment. All subjects had normal color vision and normal or corrected normal vision.

Apparatus and procedure: The apparatus and procedure in Experiment 2 were the same as those in Experiment 1.

Stimuli: Stimuli in the experiment were 20 human face figures, 10 males and 10 females, aged from 18 to 25, selected by a pilot experiment (shown in Fig.2).

Results

The first sampling parts: The results from 64 subjects are shown in Table 3.

Fig.2 Twenty human faces used in the Experiment 2

Table 3 shows that the highest frequency was "hair" (29.7%), then "outline" (25.8%) and "random" (18%). Only very few subjects chose "mouth" (0.8%), "cheek" (1.6%) or "no idea"(1.6%) as the first sampling parts. The result of χ^2 test showing that the first sampled parts were significantly not uniformly distributed (χ^2=90.25, P<0.01), which indicated that for the human face, subjects sampled information mostly from the hair or outline parts, rarely from the mouth part.

Effect of first sampling parts on visual performance: The result of ANOVA showed that in most cases, the first sampling had little effect on visual performance (P>0.05).

Sampling order: The sampling order for human faces are shown in Table 4. Both Friedman and Kendall test indicated that the sampling order was significantly not random (P<0.01), which suggested that subjects had sampling order arranged as shown in Table 4.

As for 3-D cubes, the rank correlations for human faces were statistically significant (varied from 0.755 to 0.893, P<0.01). The results showed that the sampling order was still consistent with the difference degree of the features, and suggested that the features with higher difference degree should be sampled prior to those with lower difference degree.

CONCLUSION

We sum up our results from the 2 experiments as follows: (a) for recognizing the 3-D cubes, the first sampling focused mostly on the outline parts, rarely on the center parts; while for human faces, the first sampling mostly focused on the hair and the outline parts, rarely on the the mouth and cheek parts. But, in most cases, the first sampling-position had no significant effects on the cognitive perform-

Table 3 Frequency and percentage of first sampling parts (human face)

	Outline	Center	Mouth	Eye	Cheek	Hair	Random	No idea	χ^2	P
Frequency	33	15	1	14	2	38	23	2	90.25	0.000
Percentage	25.8	11.7	0.8	10.9	1.6	29.7	18.0	1.6		

Table 4 Sampling order in different conditions (human face)

		10 features										χ^2	W	P
		Gender	Hair type	Face type	Structure	Outline	Feeling	Particular feature	Cheek	Eye	Mouth	Friedman test	Kendall's coefficient	
Task	Confirm	2.33	4.84	3.80	4.25	4.11	6.23	7.17	7.14	7.20	7.92	221.2	0.384	0.00
	Match	3.81	2.77	5.02	4.81	5.27	5.75	5.56	7.02	7.08	7.88	150.4	0.261	0.00
Display manner	Rotated	2.92	3.25	4.39	4.73	5.03	6.19	6.28	7.19	6.92	8.09	184.5	0.320	0.00
	No-rotated	3.22	4.36	4.47	4.33	4.34	5.80	6.45	6.97	7.36	7.70	151.8	0.264	0.00
Display condition	Clear	3.00	4.23	4.58	4.33	4.20	5.44	6.70	6.84	7.09	8.58	188.7	0.328	0.00
	Ambiguous	3.14	3.38	4.28	4.73	5.17	6.55	6.03	7.31	7.19	7.22	158.7	0.275	0.00
Average		3.07	3.80	4.43	4.53	4.69	5.99	6.37	7.08	7.17	7.90	327.46	0.284	0.00
Z score		1.51	1.05	0.66	0.60	0.50	–0.30	–0.54	–0.98	–1.02	–1.19			

ance. (b) the sampling order, both for 3-D cubes and for human faces, was determined by the degree of the difference among the sampled-features. The features with higher degree of this difference should be sampled prior to those with lower degree in sampling order.

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