Investigation of Semantic Properties of 260 Visual Pattern Stimuli by Online Experiment

研究論文

Investigation of Semantic Properties of 260 Visual Pattern Stimuli by Online Experiment

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Abstract

The Visual Patterns Test (VPT) (Della Sala et al., 1997, 1999) was developed to evaluate visuospatial short-term memory. The VPT uses a matrix pattern that consists of black and white cells. It has been indicated that verbal encoding occurs simultaneously with visual encoding during the performance of visual memory tasks, and that it is difficult to separate the verbal processing component in the VPT (Brown LA et al., 2006). Therefore, when employing matrix patterns as experimental material, it is necessary to clarify the extent to which verbal encoding takes place before creating a stimulus list. In the current study, the stimulus valence of the semantics of 260 matrix patterns was measured through an online experiment (n = 41). In the results, we report basic statistics for each pattern complexity and stimulus valence values for all stimuli.

Keywords: visual short-term memory, visual patterns test

1. Purpose

Nonverbal short-term memory is divided into visual and spatial memory, and tasks have been proposed to measure the extent of each type of memory. The Corsi Block task, developed by Corsi (1972), is a task to memorize and recall the position and sequence of nine squares (cubes) placed in different positions. The Corsi Block task has been studied in terms of the relationship between the length and complexity of the path of the stimulus sequence and the range of memory for the experimental materials. In addition, standard methods and standardized data (Berch et al., 1998, Kessels et al., 2000, etc.) have been reported as a memory range task, and it is widely used in the fields of cognitive psychology and neuropsychology.

The Visual Patterns Test (VPT) was developed as a typical task to measure the range of visual short-term memory (Della Sala et al., 1997). The VPT consists of a matrix of black and white cells (Fig. 1), and has been used as an experimental stimulus in visual short-term memory research (Phillips & Christie, 1977). The VPT was developed by Della Sala et al. (1997), and two stimulus lists (Pattern A and B) are used in their standardized test. The standardized test has been available in the UK for some time, and the test itself and its stimulus lists are not easily accessible in 2023.

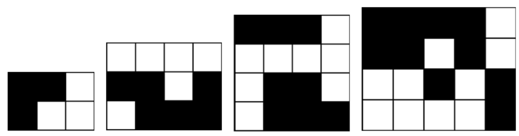

Fig. 1. Examples of visual pattern stimuli (levels 3, 6, 8, and 10 from left to right)

According to Pavio's (1971) dual encoding theory, visual information, which is nonverbal information, is considered to be encoded simultaneously in visual images and verbally. Therefore, memory performance includes the influence of verbal and nonverbal memory resources. Therefore, in order to use visual pattern stimuli as material for visual memory tasks, it is necessary to control the degree of verbal encoding due to semantics produced by the composition of black and white cells. By controlling the degree of semantics that enables verbal encoding, we can control access to long-term memory for semantic judgments during visual information processing, which will expand the range of use of experimental materials.

Brown et al. (2006) reexamined the degree of semanticity that enables verbal encoding of stimuli in the VPT, and developed a modified version of the test, in which participants were asked to rate the degree of labeling of 84 original stimuli on a 5-point scale as a verbal encoding, and to verbally report. Moreover, Orme (2009) had the original stimuli rated on a 7-point scale of meanings by teaching " This is how much of the pattern you can remember by giving all or part of it labels or recognizing shapes or configurations that you may be able to remember without being able to explicitly describe." for 978 stimuli (complexity levels 5–15), and created high and low semantic stimulus sets for all complexity levels. The stimuli evaluated in these studies were visual and were rated on a 7-point scale of meaningfulness. The stimuli evaluated in these studies have been used in related studies on visual working memory (Orme et al., 2017, Hamilton et al., 2018). However, these stimulus lists are not easily accessible in 2023.

Therefore, in the current study, we created visual pattern stimuli as experimental material for visual short-term memory to easily control semantics, as well as a list of stimuli clarified by an evaluation experiment, and made the latter available online. The experiment will be conducted online, taking into account the fact that various online experiment libraries and recruitment systems for participants have been developed in recent years. In this online experiment, taking into account differences in concentration among participants, we set four levels of complexity, namely 3 × 2 (3 black cells: level 3), 4 × 3 (6 black cells: level 6), 4 × 4 (8 black cells: level 8), and 5 × 4 (10 black cells: level 10), with 20 pattern stimuli for level 3, and 80 pattern stimuli each for levels 6, 8, and 10.

Using the selected stimuli, this study examines and reports (1) the basic statistics of the semantic properties of these stimuli for each level of complexity, and (2) whether these stimuli can be classified as high or low semantic stimuli when divided into two groups based on their mean values for each level of complexity. Finally, we will provide images of the evaluated stimuli, their semantic evaluation values, and the information used to create the stimuli for each stimulus (information on stimulus patterns denoted by 0 and 1) to the public [1].

2. Method

2.1. Participants

Fifty candidate participants were recruited through CrowdWorks, with 41 (27 males and 14 females) completing responses that were included in the analysis. Participants were aged 18 years or older and ranged from 26 to 61 years (mean age 40.93 years). Participants were able to understand the instructions and consent forms in Japanese. Participants were paid 300 yen via CrowdWorks.

2.2. Materials

The visual pattern was a checkered grid of black and white cells. The size of a single cell was 50 × 50 pixels, and the boater lines between cells were black and 2 pixels wide. The visual patterns were of four complexity levels: 3 × 2 (3 black cells: level 3), 4 × 3 (6 black cells: level 6), 4 × 4 (8 black cells: level 8), and 5 × 4 (10 black cells: level 10). The size of the visual patterns was determined by the visual pattern level. The sizes of the visual patterns were 158 pixels × 106 pixels for level 3, 210 pixels × 158 pixels for level 6, 210 pixels × 210 pixels for level 8, and 262 pixels × 210 pixels for level 10.

2.3. Procedure

The experiment was conducted as an online experiment. The experimental program was created in jsPsych (de Leeuw, 2015). The experiment was limited to desktop or laptop computers. After giving their consent to participate in the experiment, participants were asked to watch a video introducing how the experiment was conducted. After viewing the video, the participants were asked to complete an online participant profile questionnaire. Next, they were instructed to keep the distance between the display and their face at approximately 50 cm, and then a screen for adjusting the stimulus size for each participant using the virtual-chinrest plugin of jsPsych was displayed for adjustment (using this plugin, 200 pixels in width was set to be 2.2 cm wide on the participants' screens). After adjustment of the stimulus size, the evaluation experiment was conducted.

At the beginning of the evaluation experiment, in order to help participants understand how to evaluate the meaning of the shapes, they were told, "For each pattern, please rate how much meaning you feel you can attach the pattern. In your evaluation, rate the degree to which you feel you might be able to attach meaning to all or part of the black-and-white-pattern shapes and recall them without being able to explain them explicitly." These instructions followed the method of Orme (2009). After that, the evaluation of each stimulus was started.

After the start of the evaluation experiment, a figure was placed in the center of the screen and the participants were told, "Please evaluate the meaning of the image by pressing one of the numbers 1 to 7" below the figure, with 1 = Not at all, 2 = Not very much, 3 = Not much, 4 = Neither, 5 = Slightly, 6 = Somewhat, 7 = Very much. Participants evaluated the semantics of the images by pressing 1 to 7 with the mouse according to the instructions. When the participant responded with a button, the next stimulus was presented.

The patterns were presented in a fixed order (level 3, level 6, level 8, and level 10) for the complexity group, and the order of presentation within each group was randomized for each participant. For an attentional check, we included a stimulus at level 8 that required participants to give a specific response. Participants rated 260 patterns in total. They were free to take breaks during changes in levels of complexity. The duration of the experiment was about 30 minutes.

This experiment was approved by the Shizuoka University Research Ethics Committee for Human Subjects

3. Result

Table 1 shows the mean, median, standard deviation, maximum, and minimum values of semantics for each complexity level. Level 3 was excluded from the analysis because there were 20 stimuli, and the mean values of semantics for levels 6 to 10 were analyzed. First, we examined whether the semanticity differed by complexity (number of black cells) using a one-factor between-participants analysis of variance for the three conditions from level 6 to level 10. The results showed that the main effect was significant [$F(2,158) = 6.46$, $MSe = 0.744$, $p = .002$, ${}_{p}\eta^2 = 0.05$]. Multiple comparisons using the Holms method revealed that level 6 > level 8 and level 6 > level 10 (p < .05). Although it is not clear whether the mean semanticity of the stimuli above level 10 is higher than that of level 6, since we did not evaluate them in this study, it is possible that the mean semanticity does not increase above level 6 even if the level of complexity is increased. We can expect that higher levels would be more likely to produce stimuli with lower semantics. In addition, since there were cases in which no difference was observed in the mean semantic value between levels, it can be said that careful control between stimuli is necessary.

Table 1. Basic statistics on semantics at each level of complexity

	level 3	level 6	level 8	level 10
MEAN	4.04	3.40	3.01	2.95
MEDIAN	3.34	3.05	2.80	2.85
SD	1.41	1.08	0.79	0.65
MAX	6.32	6.49	6.12	5.24
MIN	2.41	1.88	1.98	2.07

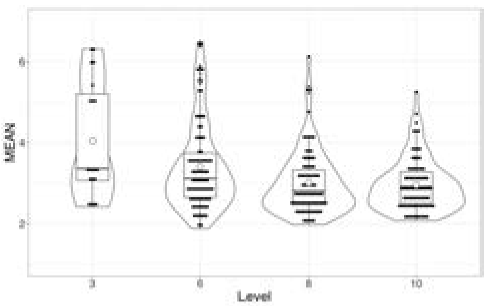

Fig. 2 Distribution of semantics ratings for each level of complexity (○ = Mean)

The distribution of semantics of the stimuli created in this study is shown in Fig. 2. The distribution of the evaluation values of the stimuli at each level suggests that many low-semanticity stimuli were created at all levels. It is possible that stimuli with high semantics are difficult to produce by random creation.

In order to examine whether the stimuli could be classified as high or low in semantics for each level of complexity, we decided to conduct an upper- and lower-order analysis based on the mean value for each level of complexity. The number of above-mean and below-mean stimuli, their mean values, and standard deviations for each complexity level are shown in Table 2. When an unpaired t-test was conducted on the mean for each level of complexity, significant differences were found in all conditions [level 3, $t(17) = 7.69$, $p < .001$, $d = 3.57$; level 6, $t(78) = 11.5$, $p < .001$, $d = 2.65$; level 8, $t(78) = 10.8$, $p < .001$, $d = 2.46$, and level 10, $t(78) = 11.2$, $p < .001$, $d = 2.55$]. From this result, it can be said that it is possible to control the semantics of the visual pattern stimuli within the complexity level as a method of using visual pattern stimuli.

Table 2. Mean semantic high and low stimulus for each level of complexity.

	level 3			level 6		
	Numbers	MEAN	SD	Numbers	MEAN	SD
Above the average	8	2.99	0.39	31	2.72	0.38
Below the average	12	5.63	0.58	49	4.47	0.95

	level 8			level 10		
	Numbers	MEAN	SD	Numbers	MEAN	SD
Above the average	32	2.51	0.26	32	2.54	0.26
Below the average	48	3.75	0.73	48	3.58	0.56

4. Discussion

In this study, we evaluated the semantics of 260 visual pattern stimuli in an online experiment. The results of the experiment showed that the stimuli were divided into groups of high and low semanticity for all difficulty levels (level 3 to level 10) by dividing them into two groups based on the mean value. The distribution of semanticity of the stimuli in Fig. 2 shows a tipped-top type distribution, suggesting that as the level increases (the number of cells increases), it is difficult to create visual pattern stimuli with high semanticity.

Figures with specific patterns (line symmetry, point symmetry, letter shape), such as those in Figures 6-2 and 6-24 in Appendix 2, were evaluated as highly semantic even in the online experiment. This result suggests that the stimuli were appropriately evaluated even in the online experiment. Although there are some limitations to the procedures of online experiments, such as the control of stimulus size, in this study, we controlled the stimuli to the extent possible in the experimental library. In particular, no participant reported any problems with the procedure, suggesting that the evaluation experiment was feasible with careful instruction.

In this study, we did not conduct an experiment to evaluate memory using the created stimuli. In order to improve the validity of the evaluation values, it will be necessary to confirm the validity of the stimuli by actually using them as experimental stimuli. This is an issue to be addressed in the future.

The figures created in this study, their data, and evaluation values are available on our website.

5. References

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Footnotes

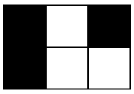
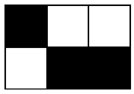
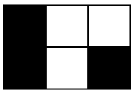
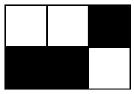
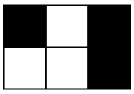
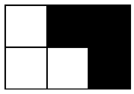
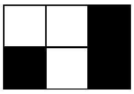
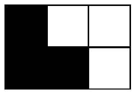
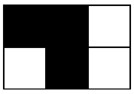
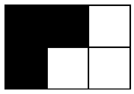
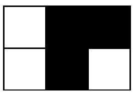
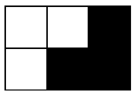
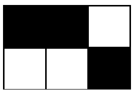
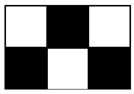
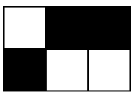
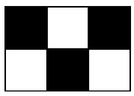
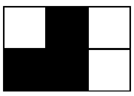
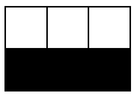
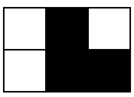
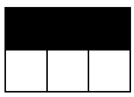
1) The images of the visual pattern stimuli evaluated, the data used to create them, and the statistics are available at the following URL: https://osf.io/gcj6e/

2) Visual pattern stimuli were created in Python3. ChatGPT was partially used to create the code.

3) DeepL was partially used to create the English text.

Appendix 1. List of stimuli at level 3 of complexity

(stimulus number, image, semantic mean, standard deviation)

No	IMG	MEAN	SD	No	IMG	MEAN	SD
17		2.41	1.20	13		3.37	1.73
2		2.44	1.29	19		3.41	1.69
11		2.54	1.45	5		4.93	1.42
12		2.54	1.36	10		5.02	1.52
8		3.02	1.39	1		5.12	1.45
16		3.07	1.62	9		5.41	1.22
18		3.17	1.70	3		5.93	1.19
7		3.24	1.79	15		6.02	1.17
6		3.27	1.52	4		6.29	0.93
14		3.34	1.51	20		6.32	0.99

Appendix 2. List of stimuli at level 6 complexity
(stimulus number, image, semantic mean, standard deviation)

No	IMG	MEAN	SD	No	IMG	MEAN	SD	No	IMG	MEAN	SD	No	IMG	MEAN	SD
44		1.88	1.10	49		2.66	1.42	46		3.15	1.68	55		3.83	1.60
76		2.05	1.28	23		2.68	1.46	45		3.17	1.43	68		4.02	1.86
79		2.10	1.14	24		2.68	1.31	1		3.20	1.45	42		4.10	1.58
64		2.12	1.17	80		2.68	1.47	40		3.22	1.47	75		4.20	1.58
65		2.12	1.05	61		2.76	1.48	58		3.22	1.54	34		4.22	1.59
27		2.20	1.36	74		2.76	1.37	69		3.22	1.71	21		4.34	1.57
60		2.27	1.36	6		2.80	1.45	13		3.34	1.61	22		4.44	1.58
7		2.29	1.19	26		2.80	1.40	18		3.34	1.64	5		4.61	1.64
67		2.32	1.35	53		2.83	1.46	72		3.37	1.85	71		4.63	1.73
47		2.34	1.17	30		2.85	1.44	12		3.46	1.40	39		4.68	1.78
4		2.39	1.30	20		2.88	1.72	52		3.46	1.70	48		4.68	1.78
50		2.44	1.16	32		2.93	1.59	70		3.46	1.64	29		5.22	1.41
10		2.46	1.16	35		2.93	1.57	78		3.49	1.66	59		5.34	1.44
37		2.49	1.36	25		2.95	1.53	77		3.51	1.34	73		5.44	1.60
38		2.51	1.08	51		2.95	1.45	3		3.54	1.60	57		5.61	1.18
8		2.54	1.58	43		2.98	1.65	36		3.59	1.84	66		5.71	1.47
14		2.54	1.52	9		3.02	1.46	56		3.59	1.69	15		5.85	1.46
54		2.59	1.43	31		3.02	1.33	63		3.59	1.95	62		5.90	1.41
16		2.61	1.36	28		3.05	1.56	19		3.63	1.53	2		6.37	1.16
33		2.61	1.67	11		3.07	1.66	17		3.71	1.74	41		6.49	0.90

Appendix 3. List of stimuli at level 8 complexity
(stimulus number, image, semantic mean, standard deviation)

No	IMG	MEAN	SD	No	IMG	MEAN	SD	No	IMG	MEAN	SD	No	IMG	MEAN	SD
54		1.98	1.04	30		2.46	1.34	75		2.80	1.42	67		3.34	1.53
52		2.12	1.31	38		2.46	1.40	19		2.83	1.63	29		3.49	1.58
45		2.15	1.24	48		2.46	1.31	59		2.83	1.64	50		3.49	1.85
62		2.17	1.45	41		2.49	1.33	64		2.85	1.89	11		3.54	1.72
77		2.17	1.05	20		2.51	1.58	26		2.88	1.47	28		3.54	2.01
21		2.20	1.23	57		2.51	1.57	42		2.93	1.51	78		3.54	1.67
33		2.20	1.21	40		2.54	1.42	72		2.98	1.39	49		3.61	1.45
16		2.22	1.26	39		2.59	1.70	15		3.00	1.52	55		3.71	1.55
7		2.24	1.26	60		2.59	1.48	31		3.05	1.47	44		3.76	1.67
43		2.24	1.39	76		2.59	1.32	47		3.10	1.59	13		3.78	1.51
66		2.24	1.36	37		2.61	1.24	10		3.12	1.44	36		3.83	1.73
46		2.27	1.40	17		2.63	1.39	34		3.12	1.62	63		4.07	1.62
51		2.29	1.45	32		2.63	1.30	23		3.15	1.42	80		4.15	1.80
18		2.34	1.28	8		2.66	1.59	1		3.17	1.60	24		4.17	1.61
69		2.34	1.42	5		2.71	1.60	2		3.20	1.45	71		4.17	1.66
65		2.39	1.26	61		2.71	1.44	9		3.22	1.54	12		4.20	1.42
56		2.41	1.43	53		2.76	1.53	68		3.22	1.52	14		4.76	1.70
70		2.41	1.14	35		2.78	1.67	73		3.27	2.09	4		5.22	1.67
79		2.44	1.21	3		2.80	1.47	22		3.32	1.82	27		5.39	1.41
6		2.46	1.32	74		2.80	1.44	25		3.32	1.79	58		6.12	1.35

Appendix 4. List of stimuli at level 10 complexity
(stimulus number, image, semantic mean, standard deviation)

No	IMG	MEAN	SD	No	IMG	MEAN	SD	No	IMG	MEAN	SD	No	IMG	MEAN	SD
14		2.07	1.06	45		2.51	1.36	29		2.85	1.39	3		3.29	1.82
7		2.10	1.14	52		2.51	1.43	53		2.88	1.42	17		3.29	1.82
27		2.10	1.09	57		2.51	1.31	8		2.90	1.59	43		3.29	1.49
69		2.15	1.30	78		2.51	1.73	51		2.90	1.67	49		3.29	1.49
6		2.20	1.12	11		2.54	1.29	72		2.90	1.41	64		3.41	1.53
62		2.20	1.35	61		2.56	1.38	34		2.93	1.74	1		3.44	1.69
23		2.24	1.26	16		2.59	1.58	63		2.95	1.53	58		3.56	1.61
28		2.27	1.23	42		2.59	1.60	76		2.95	1.70	77		3.66	1.89
31		2.27	1.16	67		2.59	1.26	21		2.98	1.51	38		3.68	1.29
32		2.27	1.32	24		2.61	1.43	22		3.05	1.69	50		3.68	1.63
9		2.34	1.06	30		2.61	1.53	55		3.05	1.56	80		3.80	1.62
25		2.34	1.46	47		2.63	1.48	40		3.07	1.62	74		3.83	1.67
39		2.34	1.24	2		2.66	1.57	46		3.07	1.46	18		3.85	1.49
79		2.34	1.26	56		2.66	1.41	54		3.07	1.65	71		3.88	1.65
35		2.37	1.13	66		2.68	1.49	68		3.07	1.47	65		4.24	1.50
37		2.37	1.20	4		2.71	1.42	12		3.10	1.53	33		4.29	1.58
75		2.39	1.22	10		2.80	1.58	19		3.12	1.35	60		4.32	1.62
48		2.41	1.26	13		2.83	1.50	26		3.15	1.78	59		4.49	1.58
20		2.46	1.53	5		2.85	1.42	70		3.20	1.69	73		4.71	1.50
44		2.49	1.55	15		2.85	1.51	36		3.27	1.50	41		5.24	1.50