A study on thresholds of perceptual size on geometric figures

Hsinfu Huang*, Dengchuan Cai**, Yingtzu Chen***

* *National Yunlin University of Science and Technology, Department of Industrial Design Taiwan, g9131701@yuntech.edu.tw.*
** *National Yunlin University of Science and Technology, Department of Industrial Design Taiwan, caidc@yuntech.edu.tw.*
*** *National Yunlin University of Science and Technology, Department of Industrial Design Taiwan, g9131715@yuntech.edu.tw.*

Abstract: geometric figures such as triangles, squares, pentagons, and circles are frequently used as the visual elements for the expression in graphic design and other basic design training courses. Many studies indicated that the perceptual accuracy of area sizes varied from geometric figures. This study aims to explore the perceptual accuracy of area size of four geometric figures, among them are: triangle, square, pentagon, and circle. Each geometric figure is involved a sample figure with an area size of one unit and a set of 101 candidate figures. The area size of the sample figure equals to the area of a circle with a diameter of 5 cm. defining to one unit, and the area sizes of 101 candidate figures ranged from 50% to 150% and increased by 1% to the sample figure respectively. Eighty university students (40 design field and 40 non-design field) served as subjects participating the experiment. The subjects are asked to perceive the area size of the sample figure then point out a figure which has same area size with the sample figure. The main results of the current study are: 1) The geometric figures that including more number of horizontal or vertical sides will be perceived more accurately. 2) The perception sizes from the greatest to the least are in the triangle, pentagon, circle, and square sequence. 3) The differences of perceptual sizes between genders and design experiences are not significant.

Keywords *: Geometric figures, Perceptual accuracy, figure area, Threshold.*

1. Introduction

Shapes can be divided into four broad categories: geometric, natural, abstract, and nonobjective [Bevlin, 1977]. The geometric shapes exist in nature. We can find the triangle in certain leaf shapes (Figure1), square in salt crystals (Figure 2), the circle in a shell formation (Figure 3), and hexagon in beehive (Figure 4). Because the geometric shapes are regular and can be generated easily and rapidly with mathematics principles [Lial et al., 1990]. The designers and artists frequently used them as the visual elements for image expression. For example, in 18th century, Sengai [Bevlin, 1977] used three basically geometric shapes: square, triangle, and circle to construct his art works expressing the stability, order, and repose (Figure 5). The other example was the “Foxtrot B” [Milner, 1992], a form of geometric abstraction that Piet Mondrin developed with vertical and horizontal lines, flat-quadrilateral shapes, and primary colors (red, yellow and blue) arranged in a balance composition (Figure 6). The geometric shapes have dominated our environment nowadays, appearing in building, bridge, furniture, and industrial products of all kinds.

Form perception is what enables us to distinguish one form from another. The two of the main attributes of form

are size and shape (Sternberg, 2001). To gain understanding the accuracy thresholds of the size perception is important. Chuang [1991] investigated the human fuzzy comparison between two points in which stimulus presented in four orientations: horizontal, vertical up-rightward, and up-leftward. The results suggested that people make better judgment on comparing horizontal or vertical distance than that on right-upward or left-upward. In the other study [Chueng, 1992], he investigated the human fuzzy comparison between two line length in which lines presented in four orientations: horizontal, vertical up-rightward. The results showed that people judge the horizontal lines better than those of other three orientations. Shuen et al. [2002] surveyed the thresholds of human perception in three geometric figures: circle, square and rhombus. The result showed that the threshold of human perception of circle was more accurate than that of square and rhombus, however the threshold of human perception of square was same as that of rhombus. The purpose of this study is to investigate the accuracy thresholds of perceptual sizes of those basically geometric figures and to gain understanding the differences among them. The four basically geometric shapes are: triangle, square, pentagon, and circle, the definition and the area formula are given as following: (Lial et al., 1990).

Figure1. An example of triangle in a leaf shape

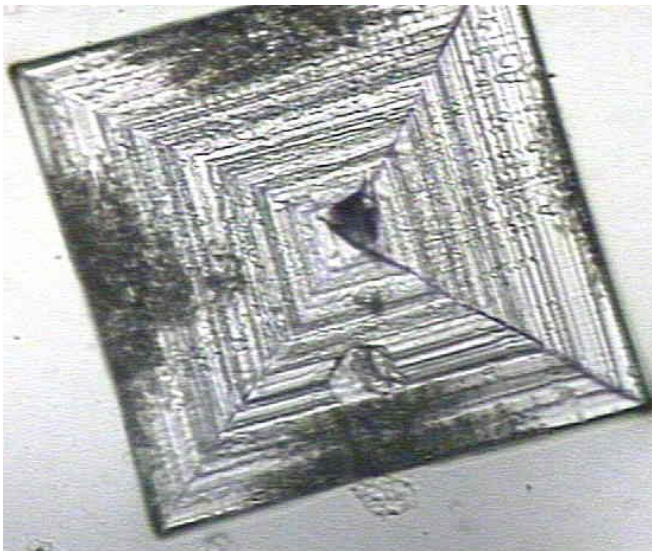

Figure 2. An example of square in salt crystal

Figure 3. An example of circle in a shell formation

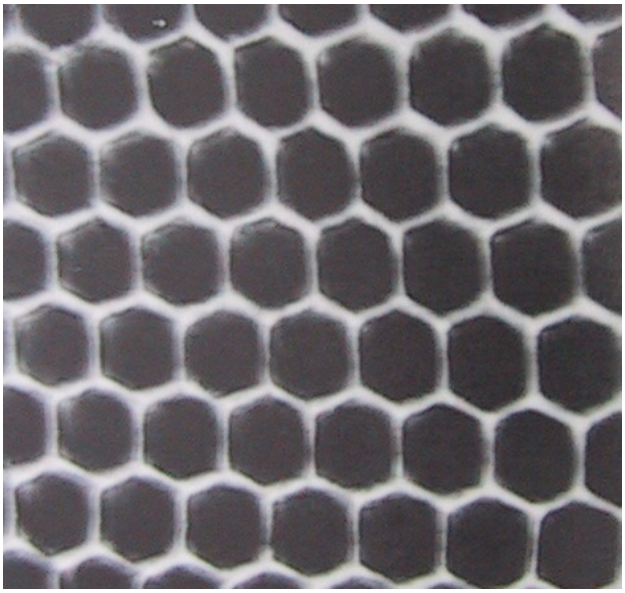

Figure 4. An example of hexagon in a beehive

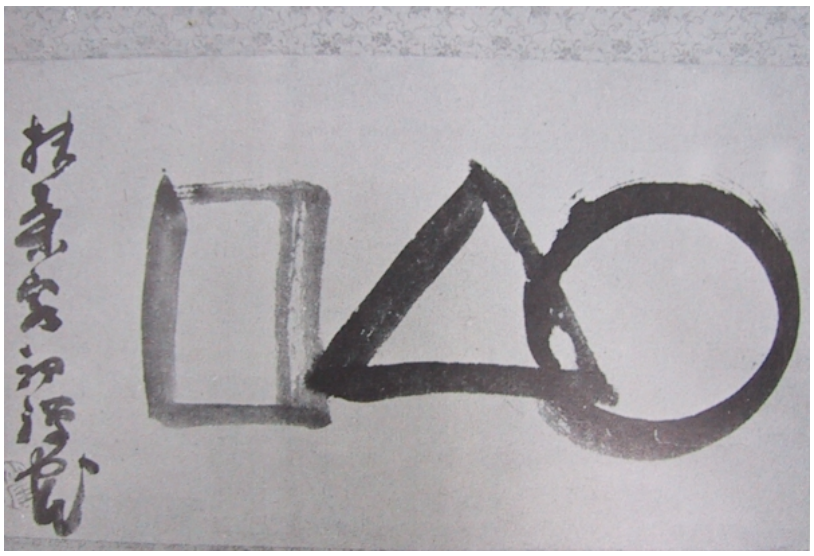

Figure 5. An art work constructed with three geometric shapes

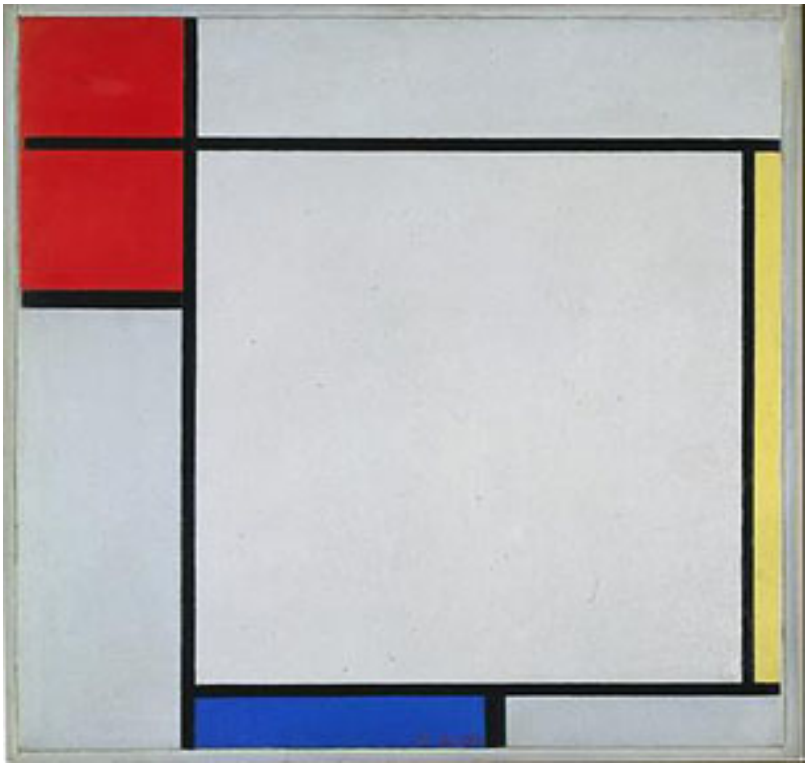

Figure 6. "Foxtrot B", a art work composed of different squares

(1) Triangle: A triangle is a plane figure having three sides and three angles. An equilateral triangle is a triangle in which all three sides are equal (figure 7). Let the side is ***a*** and its area formula will be $\sqrt{3}\ a^2/4$

(2) Square: A square is a quadrilateral whose opposite sides are equal and parallel and whose opposite angles are right angles. Let the side is ***a*** and its area formula will be a^2.

(3) Pentagon: A Pentagon is composed of five distinct segments in a plane. It's named according to the number of sides in the figure. A regular pentagon has all sides and all angles equal. Let the side of a pentagon is ***a*** and its area formula will be $5a\sqrt{4R^2-a^2}/4$

(4) Circle: A circle is the set of all points in a plane that located a fixed distance from a fixed point called its center. Let its radius is ***r***, its area formula will be πr^2.

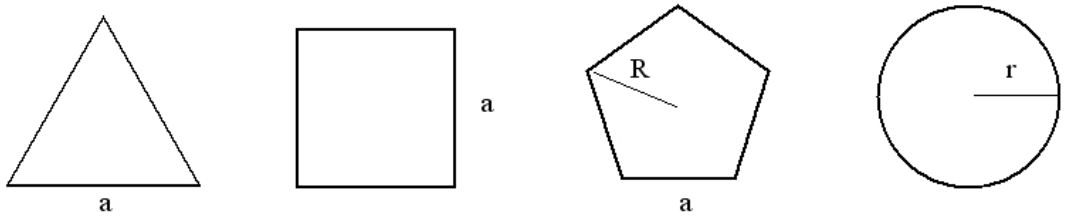

Figure.7 Four basic geometric shapes

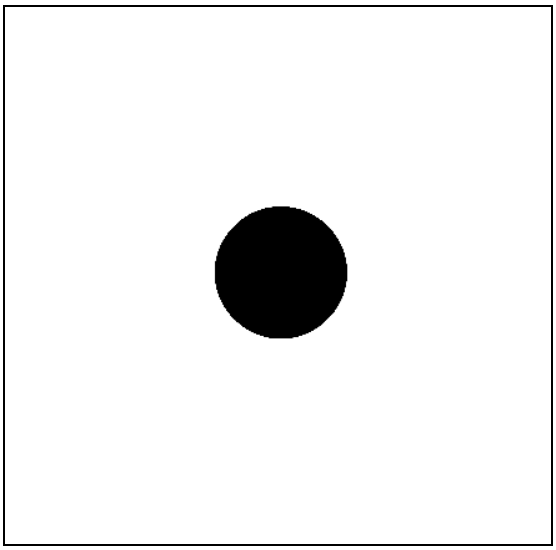

Figure8. The sample figure

2. Methods

2.1 Subject

A total of eighty university students (27females and 53 males) served as subjects participating the experiment. Their age ranged from 19 to 28 with a mean age of 21.95 years (sd = 1.85). A half of subjects majored in design field while the other half of them majored in non-design fields.

2.2 Materials

The testing materials were included four sorts of figures: triangles, squares, pentagons, and circles. Each sort of figure included a sample figure and 101 candidate figures. The area sizes of each sort of sample figure are equal to an area size of a circle with a diameter of 5 cm (figure 8). The current study defined the area size to one unit and the area sizes of 101 candidate figures ranged from 50% to 150% to the size of sample figure and increased by 1% gradually. The 101 candidate figures printed out in an A0 size (1189 mm × 841 mm) poster paper with ascending order (figure 9). All figures were black and presented on the white background paper. All these figures were drew with the software package called CorelDRAW 9.

2.3 Procedure

The subjects were explained with the study purpose and the procedure of the experiment. Four posters of candidate figures were put on an exhibition board with a height of 145 cm from the ground to the center of the posters. The comparing experiment was conducted using the method called method of limits with ascending stimulus series to determinate the thresholds of perceptual accuracy. During experiment sessions, subjects are asked to point out one figure which has the same area size with sample figure. The experiment is a within-subject design. Each subject has to test sixteen experimental conditions [i.e., four sample figures (triangles, squares,

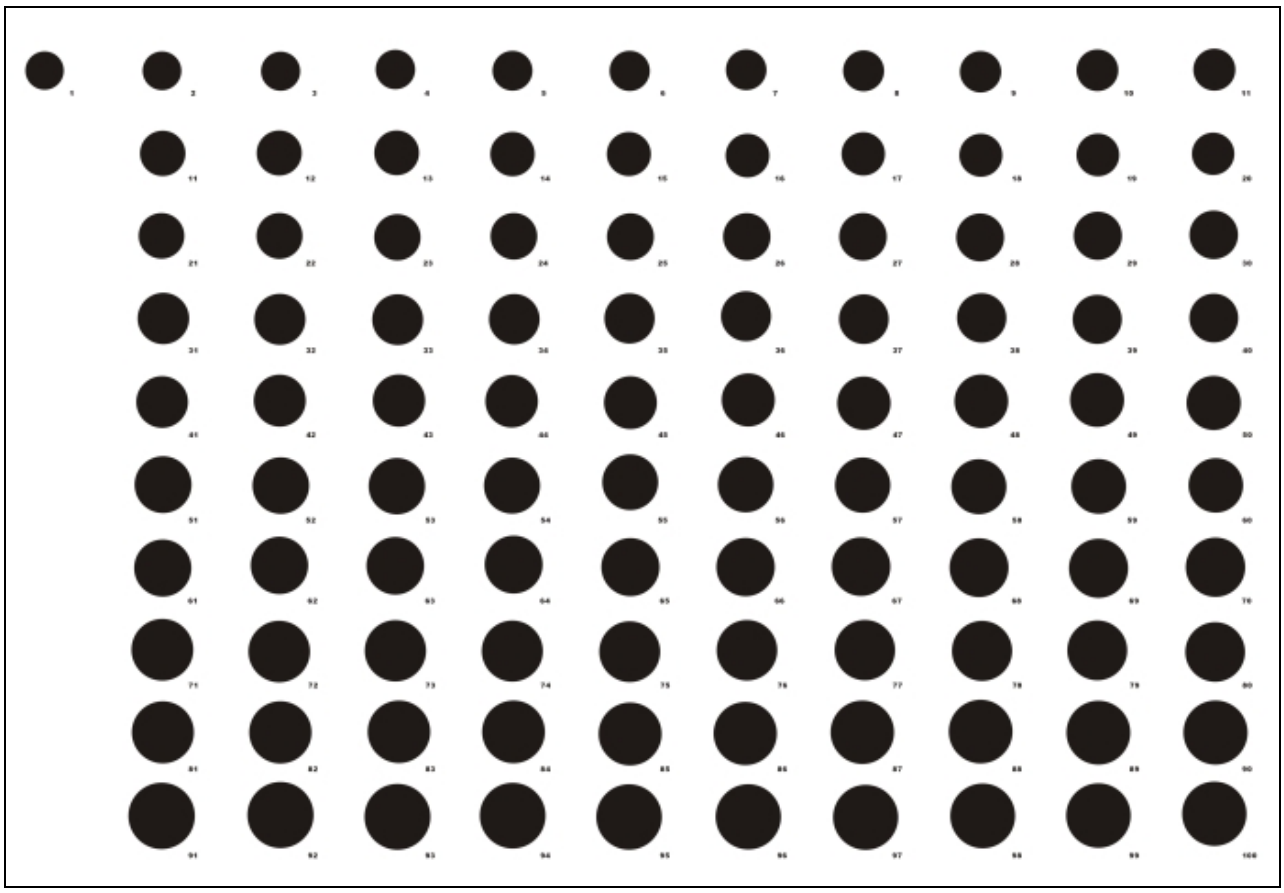

Figure9. The candidate figures

pentagons, and circles) to four candidate figures (triangles, squares, pentagons, and circles)]. The mean of experimental time is about 10 min. The subject could take a break during the experiment. The experiment was executed in an ergonomic laboratory at National Yunlin University, Taiwan. The luminance of the center of poster of candidate figures is 270 lux and is consistent through the experiment.

3. Results and discussion

This study aims to investigate the accuracy thresholds of size perception of the four basically geometric shapes: triangles, squares, pentagons, and circles. Table 1 showed the statistic descriptors (e.g., minimum, maximum, mean, and standard deviations) of accuracy percentages of size perception of the four geometric shapes. The table showed that the squire was more accurate in perception then the triangle, the triangle was more accurate in perception then the pentagon, the pentagon was more accurate in perception then the triangle. The accuracy thresholds of size perception of the four shapes from the most to the least accurate are in the square (difference: 0.38%), triangle (difference: 1.85%), pentagon (difference: 2.38%), and circle sequence (difference: 4.13%). From these results we can conducted them as following: the geometric figures that including more number of horizontal or vertical sides will be perceived more accurately. This result is consistent with the findings of Chuang [1991]. It reported that people make better judgment on comparing horizontal or vertical distance than that on right-upward or left-upward.

Table 2 was the results of t-test with accuracy percentage of 100. The table showed that the differences between perceptual size and real size were not significant in square and triangle. However, for circle and pentagon, the differences were significant. That is, we can perceive exactly in the size of square and triangle while can not exactly perceive in pentagon and circle.

Table1 Difference in area size of same figures

Figure	N	Min	Max	Mean	SD	Differences
Circle	80	79	108	95.875	6.48	-4.13
Triangle	80	79	123	98.15	8.50	-1.85
Square	80	80	140	100.375	8.93	0.38
Pentagon	80	81	119	97.6125	8.00	-2.38

Table2 Duncan test [t-test compare with 100%]

Figure	N	Mean	t-values	Sig.
Circle	80	95.875	-5.573	0.000
Triangle	80	98.15	-1.804	0.074
Square	80	100.375	0.400	0.689
Pentagon	80	97.6125	-2.570	0.012

Table 3 The descriptive statistics of perceptual area size for each figure

Sample Fig.	Candidate Fig.	N	Mean	Std.	Differences	Duncan Tests
Circle	Triangle	80	84.04	18.67	-15.96	Triangle > Pentagon > Square
	Pentagon	80	97.14	12.86	-2.86	
	Square	80	104.30	10.67	4.3	
Triangle	Pentagon	80	110.46	19.82	10.46	(Pentagon, Circle) > (Circle, Square)
	Circle	80	113.49	20.82	13.49	
	Square	80	116.80	23.15	16.80	
Square	Triangle	80	82.50	22.08	-17.5	Triangle > (Pentagon, Circle)
	Pentagon	80	92.95	11.73	-7.05	
	Circle	80	94.60	12.15	-5.40	
Pentagon	Triangle	80	87.50	19.05	-12.5	Triangle > Circle > Square
	Circle	80	101.34	11.20	1.34	
	Square	80	108.31	12.88	8.31	

Table 3 showed the statistic descriptors of perception sizes of the four figures comparing with the other three figures respectively. From the table we have: a) Using circle as sample figure to compare with the other three figures indicated that the perception size of triangle was greater than that of pentagon and the perception size of pentagon was greater than that of square. b) Using triangle as sample figure to compare with the other three figures indicated that the perception size of pentagon and circle was greater than that of circle and square. c) Using square as sample figure to compare with the other three figures indicated that the perception size of triangle was greater than that of pentagon and circle. d) Using pentagon as sample figure to compare with the other three figures indicated that the perception size of triangle was greater than that of circle and the perception size of circle was greater than that of square. From the results discussed above we can summarize them as following: the perception sizes from the greatest to the least are in the triangle, pentagon, circle, and square sequence.

The current study compared the difference of perceptual size between genders and design experience. The results

of t-test are shown in Table4. The table showed that the differences of perceptual sizes between gender and design experience are not significant.

Table4 T-test of the effects in perceptual accuracy of area size between gender and design experience.

Type of comparison		Design experience		Gender	
Sample Fig.	Candidate Fig.	t	p	t	p
Circle	Circle	-.895	.374	.385	.701
	Triangle	-.542	.589	-.378	.707
	Square	-.229	.819	.887	.378
	Pentagon	-.912	.365	-.518	.606
Triangle	Circle	.379	.706	1.763	.082
	Triangle	-.445	.658	.029	.977
	Square	-.288	.774	.060	.952
	Pentagon	-.219	.827	-.684	.496
Square	Circle	-1.181	.241	.624	.534
	Triangle	-.534	.595	.282	.779
	Square	-1.411	.162	.583	.561
	Pentagon	-.953	.344	.213	.832
Pentagon	Circle	-1.961	.053	-.756	.452
	Triangle	-1.309	.195	.339	.735
	Square	-.545	.588	-.010	.992
	Pentagon	-1.391	.168	-.661	.510

4. Conclusions

This study aims to explore the thresholds of perceptual size of four geometric figures (triangle, square, pentagon, and circle). Based on the results of the current experiment, the findings can be summarized as following: a) The accuracy thresholds of perceptual size of four geometric figures from the most to the least accurate are in the square, triangle, pentagon, and circle sequence. That is the geometric figures that including more number of horizontal or vertical sides will be perceived more accurately. b) The perceptual size of triangle is greater than that of pentagon, the perceptual size of pentagon is greater than that of circle, and the perceptual size of circle is greater than that of square. In other word, the perception sizes from the greatest to the least are in the triangle, pentagon, circle, and square sequence. c) The differences of perceptual sizes between genders and design experiences are not significant. That is, the perception is a popular function and is commonly and equally involved in everyone. The comparing test was conducted using the method of limits with ascending stimulus series to determinate the thresholds, the same experiment with descending series should be an interesting topic for further study. The testing materials were two-dimension figures, the geometric form in three-dimension shall also be a valuable subject in the future.

Reference

Bevlin, Marjorie Elliott, 1977, Design through discovery, 3rd Ed., Holt, Rinehart and Winston, New York.

Chuang, Ming-Chuen, 1991, A study of human fuzzy comparison of distances between two point, Journal of Mingchi Institute of Technology, vol. 23, pp. 115-127.

Chuang, Ming-Chuen, 1992, A study of human fuzzy comparison of distances between two line lengths, Journal of Mingchi Institute of Technology, vol. 24, pp. 175-188.

Lial, Margaret L., Steffensen, Arnold R. Johnson, Murphy L., 1990, Essentials of geometry for college students, Scott, Foresman and company, London.

Milner, John, 1992, Mondrian, Abbeville Publishing Group, New York.

Robert L. Solso, 1991, Cognitive psychology, Allyn and Bacon, Boston.

Shuen, Tzung-huang, Cai, Dengchuan, Hunag, Hsin-fu, Cheng, Chia-an, 2002, A study on the sensitivity of shapes and orientations, Bulletin of the 7th Chinese institute of design conference, pp. 357-360.

Sternberg, Robert J., 2001, Psychology in search of human mind, 3rd Ed., Harcourt College Publishers, New York.