Details of the Matching Experiment

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The experiments were conducted in 2013-2015 at the Department of Psychological Sciences of Purdue University. The text is to serve as a metafile for the results of these experiments placed as Excel files in Purdue University Research Repository (PURR, http://research.hub.purdue.edu/). Each file corresponds to one participant in one experiment.

1 Participants

All the participants were students at Purdue University. The second author of this paper, labeled as P3, participated in all the experiments. Two persons (P1 and P2) participated in Experiments 1(a) and 2(a), and two other persons (P4 and P5) in Experiments 1(b), 2(b), 2(c), 3(a), and 3(b). All participants were aged around 25 and had normal or corrected to normal vision.

2 Stimuli and Procedure

Visual stimuli consisting of curves and (sometimes) dots were presented on a flat-panel monitor. They were grayish-white on a comfortably low intensity background. The diameter of the dots and the width of the curves was 5 pixels (px). The participants viewed the stimuli in darkness using a chin rest with a forehead support at the distance of 90 from the monitor, making 1 screen pixel approximately 62 sec arc. In each trial the participants were asked to match a fixed stimulus by

adjusting a variable stimulus by rotating a trackball using their dominant hand. Once a response was made to the participant's satisfaction, she or he clicked a button on the trackball device to end this trial, and a new stimulus appeared half a second later. Each experiment took several days, each of which consisted of about 200 trials conducted with a 10-min break in the middle; each such session was preceded by a practice series of 10 trials (which were not recorded).

2.1 Experiment 1(a)

Each trial began with presenting two circles with a dot in the first quadrant of each circle (as shown in Figure 1, top panels). The radius of each circle was 160 px. The dot in the upper left circle was fixed at one of randomly chosen six positions. Using the center of its circle as the origin, they can be represented equivalently using the rectangular coordinates: {(24 px, 48 px), (32 px, 32 px), (32 px, 64 px), (48 px, 24 px), (64 px, 32 px), (64 px, 64 px)} or the polar coordinates: {(53.67 px, 63.43 deg), (45.25 px, 45 deg), (71.55 px, 63.43 deg), (53.67 px, 26.57 deg), (71.55 px, 26.56 deg), (90.51 px, 45 deg)}. Hence the experimental design contained a 2×2 "rectangular" subdesign, {32 px, 64 px}×{32 px, 64 px}, and a 2×2 "polar" subdesign {53.67 px, 71.55 px}×{63.43 deg, 26.57 deg}.

The position of the dot in the bottom right circle was controlled by the trackball, until its location matched that of the fixed one. Once a response was made, the program recorded the locations of the target dot and the matching dot in both rectangular coordinates and polar coordinates. There were 1200 trials overall with approximately 200 trials per treatment.

2.2 Experiment 1(b)

The horizontal coordinate and vertical coordinate of the target dot were random integers drawn before each trial from the the rectangle [20 px, 80 px)×[20 px, 80 px). This Cartesian rectangle contained the polar-coordinate rectangle [40 px, 90 px)×[30 deg, 60 deg), allowing us to analyze the data falling within it separately. The overall number of trials was 1800, of which 900 fell within the polar-coordinate rectangle. In all other respect, the procedure was the same as in Experiment 1(a).

2.3 Experiment 2(a)

Each trial began as shown in Figure 1, middle left panel. The target figure, on the left, consisted of two concentric circles together with their center. The radii of circle 1 and circle 2 were randomly chosen from the sets {16 px, 56 px, 64 px} and {48 px, 72 px, 80 px}, respectively, in a 3×3 factorial design. On the right, in the beginning of the trial, there was a dot located at (250 px, 0 px) relative to the center of the target figure. By rotating the trackball the participant aimed at matching the target figure by "blowing up" two circles from the dot on the right, one by one. Once the first matching circle was produced (inner or outer, the person could choose), the participant clicked a button on the trackball to stabilize this circle and then the program enabled him or her to "blow" the other circle. After the second match was made, the trial was terminated by clicking the same button on the trackball. The program recorded the radii of the target and matching concentric circles in each trial. There were 1800 trials overall, approximately 200 trials per treatment.

2.4 Experiment 2(b)

Experiment 2(b) was identical to Experiment 2(a) except that in each trial the radii of the target circle 1 and circle 2 were randomly chosen from four possibilities {12 px, 24 px}$\times${18 px, 30 px}. There were 1600 trials overall, about 400 trials per treatment.

2.5 Experiment 2(c)

Experiment 2(c) was identical to Experiment 2(a) except that in each trial the radius of the target circle 1 was a number randomly chosen from the uniform distribution on the interval [18 px, 48 px) and the radius of the target circle 2 was randomly chosen from the interval [56 px, 86 px). There were 1800 trials overall.

2.6 Experiment 3(a)

Examples of two floral shapes together with their centers are shown in Figure 1, bottom panels. Two such configurations were presented simultaneously in each trial. The target one was on the

left, the variable one on the right. The floral shape was generated using the function

$$x = cos(.02\pi\Delta)[70 + \alpha cos(.06\pi\Delta) + \beta cos(.1\pi\Delta)], \quad (1)$$
$$y = sin(.02\pi\Delta)[70 + \alpha cos(.06\pi\Delta) + \beta cos(.1\pi\Delta)],$$

where x, y stand for the rectangular coordinates. Amplitude α and amplitude β of the left floral shape were randomly chosen from the sets {-18 px, 10 px, 14 px} and {-16 px, -12 px, 20 px}, respectively. Δ was varied from 0 to 99 with an increment of 1 at each step. At each step, a point with coordinates (x, y) was drawn to the screen and each floral shape was composed of 100 such points. The α and β for the shape on the right was controlled by rotating the trackball. The program converted the horizontal (vertical) component of the rotation to the change of α (respectively, β). The initial values for these amplitudes were randomly picked from the interval [-35 px, 35 px). There were 1800 trials overall, about 200 trials per treatment.

2.7 Experiment 3(b)

Experiment 3(b) was identical to Experiment 3(a) except that the two amplitudes for the target shape were randomly chosen numbers from the interval [-30 px, 30 px).

3 Analysis

In each experiment we deleted outliers, defined, rather informally, as the matching values that were too far from the target values. The outliers made less than 1% of all data. (Note that the files in the repository do not have the outliers deleted.)

In Experiment 2b the design was 2×2. In Experiment 1a there were two 2×2 subdesigns, the "rectangular" and "polar" ones. In Experiment 2a and 3a the design was 3×3 and the analysis was made for each of the nine possible 2×2 subdesigns. In Experiments 1b, 2c, 3b the values of the target stimulus were first dichotomized into below-median and above-median values, forming a

2×2 factorial design in each of them.

Once a 2×2 design was formed, the responses (matching values of the variable stimuli) were dichotomized as described in Section 7 of the main text, by choosing all possible combinations of four integer values in the intervals

$$
\begin{aligned}
x_1 &\in \{\max[\min X_{12}, \min X_{41}], \min[\max X_{12}, \max X_{41}]\}, \\
x_3 &\in \{\max[\min X_{23}, \min X_{34}], \min[\max X_{23}, \max X_{34}]\}, \\
y_2 &\in \{\max[\min Y_{12}, \min Y_{23}], \min[\max Y_{12}, \max Y_{23}]\}, \\
y_4 &\in \{\max[\min Y_{41}, \min Y_{34}], \min[\max Y_{41}, \max Y_{34}]\}
\end{aligned}
$$

The analysis afterwards consisted in computing the value of ΔC. The number of dichotomizations in each 2×2 (sub)design was between 3024 and 11,663,568.