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# Introduction

Similarity between items is an important aspect in many area of psychology, e.g., categorization (Nosofsky & Palmeri, 1997), memory (Farrell, 2006; Jackson, Linden, Roberts, Kriegeskorte, & Haenschel, 2015; Nosofsky & Kantner, 2006), and reasoning (Heit & Rubinstein, 1994). However, similarity matrix is expensive to acquire.

What’s the problem with the traditional tasks.

# Experiment 1

In the Experiment 1, we tested the validity and the reliability of the Multi-Items Rearrangement measurement. The experiment is separated into two blocks. The first block employed the Multi-Items Rearrangement measurement to measure the similarity between abstract faces. The second block used the Paired comparison measurement to validate the result acquired from the Multi-Items Rearrangement measurement.

## Method

Participants. Ten students recruited from University of Zürich. Participants were rewarded with course credits or 30 Swiss Francs after completed the experiment.

Materials. Both Multi-Items Rearrangement task and the Paired-Comparison task shared the same set of stimuli. Color patches are used in the practice trials. The colors are randomly selected from all the possible colors in the 24 bits RGB color space. Abstract faces are used in the experiment trials. The faces are varied on four dimensions: the width between eyes, the height of eyes, the length of nose, and the position of mouth, with each dimensions have two possible configurations. The faces are shown in the Figure 1.

Procedure. Experiment 1 is consisted of two identical sessions, and the sessions are carried in two different days. Each session contains two blocks. The first block is the Multi-Items Rearrangement measurement task, and the second block is the Paired comparison measurement task. On average, each session takes about 45 minutes.

Multi-Items Rearrangement Task. The Multi-Items Rearrangement task consists of two practice trials and 12 experiment trials. In each trials, 8 items were randomly scattered on the screen without overlapping. Participants were instructed to rearrange the items by using mouse to drag-and-drop the items, and the distance between items should reflect the similarity between the items, where the farther distance between items indicates the more dissimilar between items. After participants were satisfied with the arrangement of the items, they can press space bar to continue to next trial. Participants were instruction to take as long as they want to rearrange the items.

The Multi-Items Rearrangement task requires 6 trials to complete the similarity matrix between 16 items. We repeated the procedure twice in order to obtain more accuracy measurement of the similarity matrix. The items were rearranged into different subgroup for the second repetition.

Paired-Comparison Task. The paired comparison task consists of 4 practice trials and 240 experiment trials. In each trial, two items were presented on the screen with a 9 points scale below the items. Participants were instructed to rate the similarity between the two items by clicking on the 9 points scale, with 1 to be the most similar, and 9 to be the most dissimilar. After the similarity is selected, a blank screen appeared for 1 second and was followed by the next trial. Participants were instructed to take as long as they want to complete the trial.

The Paired-Comparison task requires 120 trials to complete the similarity matrix of 16 items. We repeated the measurement twice in order to increase the accuracy of the similarity matrix.

## Results

The similarity matrix acquired from the Multi-Items Rearrangement task is based on the distance between items in the trial. If the distance between two items were measured multiple times, the average of the distance is used as the similarity between the items. The similarity matrix acquired from the Paired-Comparison task is based on the rated similarity between items. Similar to the Multi-Items Rearrangement task, if an items pair is rated multiple times, the similarity between the items pair is calculated as the average between ratings. The similarity matrices acquired from both tasks were normalized by rescaling the maximum dissimilarity in the matrix to 1. The normalization ensures that the similarity matrix acquired from the Multi-Items Rearrangement task and the similarity matrix acquired from the Paired-Comparison task are under the same scale.

To test the reliability of Multi-Items Rearrangement task and the Paired-Comparison task, we compare the similarity matrixes acquired from the first session and the second session. The comparison between the similarity matrices is done through Random Skewers method (Cheverud & Marroig, 2007). The correlation between the similarity matrices acquired from first session and the second session for both tasks of each participant are listed in Table 1. To test the validity of the Multi-Items Rearrangement task, the similarity matrices acquired from Multi-Items Rearrangement task and the similarity matrices acquired from Paired-Comparison task were compared with the Random Skewers method. The correlation between the similarity matrices are listed in Table 1, where the lowest correction is 0.85. To ensure both similarity matrices are aligned, we plotted the with acquired similarity matrices with Multidimensional Scaling, as shown in Figure 2.

The average time required to complete the Multi-Items Rearrangement task is 475.6s, and the Paired-Comparison task takes average 905.1s to complete. The time required for both tasks were compared in R (R. Core Team, 2016) with BayesFactor package (Morey & Rouder, 2015), and the data strongly supported that Paired-Comparison task takes longer than Multi-Items Rearrangement task ().

# Experiment 2

In Experiment 2, we replicated the same method used ion Experiment 1 with different material. The faces in Experiment 1 were defined with multiple discrete features. In Experiment 2, we want to test the ability of measuring the similarity matrix with material with continuous feature of Multi-Items Rearrangement task, hence we used color patches as material.

### Method

Participants. Ten students recruited from University of Zürich. Participants were rewarded with course credits or 30 Swiss Francs after completed the experiment. All the participants in Experiment 2 did not participant in Experiment 1.

Materials. Both Multi-Items Rearrangement task and the Paired-Comparison task shared the same set of stimuli. The faces from the Experiment 1 were used in the practice trials. Color patches were used in the experiment trials. 16 color patches were selected from a color wheel which was created in the CIE L\*a\*b\* color space with radius of 60 and centered at luminance set to 70, set to 20, and set to 38. All the color patches were evenly distributed on the color wheel. The color patches are shown in the Figure 2, and the RGB values of the color patches are shown in Table 2.

Procedure. The procedure of the Experiment 2 is the same as the procedure of the Experiment 1.

## Results

The similarity matrices acquired from both tasks were normalized in the same way as we did in Experiment 1. For the reliability test for both tasks, we again applied the Random Skewers method to the similarity matrices acquired from the first and the second session. The correlations between the similarity matrices are shown in the Table 3. The minimum reliability of the Multi-Items Rearrangement task is 0.79, and the minimum reliability of the Paired-Comparison task is 0.70. To test the validity of the Multi-Items Rearrangement task, we compared the average similarity metric acquired from both sessions of the Multi-Items Rearrangement task and the average similarity matric acquired from both sessions of the Paired-Comparison task with Random Skewers method. The correlations are shown in Table 3, and the lowest validity is 0.77. The similarity matrices acquired from both tasks were plotted MDS in Figure 4.

The average time for completing the Multi-Items Rearrangement task is 338.3 seconds, and the average time for completing the Paired-Comparison task is 713.9 seconds. The time required to complete both tasks were compared with BayesFactor package in R. The results shown strong evidence supports the time required to complete the Multi-Items Rearrangement task is shorter than the Paired-Comparison task ().

# Discussion

## Reliability and Validity

## Advantage and Disadvantage

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Footnotes

1[Add footnotes, if any, on their own page following references. For APA formatting requirements, it’s easy to just type your own footnote references and notes. To format a footnote reference, select the number and then, on the Home tab, in the Styles gallery, click Footnote Reference. The body of a footnote, such as this example, uses the Normal text style. (Note: If you delete this sample footnote, don’t forget to delete its in-text reference as well. That’s at the end of the sample Heading 2 paragraph on the first page of body content in this template.)]

Tables

Table 1

Reliability and Validity of Experiment 1.

|  |  |  |  |
| --- | --- | --- | --- |
| Participant | Paired-Comparison | Multi-Items Rearrangement | Validity |
| 1 | 0.98 | 0.91 | 0.95 |
| 2 | 0.87 | 0.84 | 0.91 |
| 3 | 0.78 | 0.80 | 0.91 |
| 4 | 0.79 | 0.81 | 0.85 |
| 5 | 0.87 | 0.96 | 0.87 |
| 6 | 0.81 | 0.74 | 0.91 |
| 7 | 0.94 | 0.83 | 0.87 |
| 8 | 0.95 | 0.86 | 0.86 |
| 9 | 0.91 | 0.95 | 0.91 |
| 10 | 0.85 | 0.71 | 0.89 |

Table 2

The RGB values of the color patches used in Experiment 2.

|  |  |  |  |
| --- | --- | --- | --- |
| Item | R | G | B |
| 1 | 255 | 90 | 109 |
| 2 | 255 | 97 | 65 |
| 3 | 255 | 116 | 0 |
| 4 | 255 | 137 | 0 |
| 5 | 238 | 156 | 0 |
| 6 | 204 | 171 | 0 |
| 7 | 170 | 182 | 0 |
| 8 | 141 | 188 | 49 |
| 9 | 118 | 191 | 101 |
| 10 | 107 | 190 | 145 |
| 11 | 117 | 180 | 180 |
| 12 | 149 | 176 | 204 |
| 13 | 191 | 162 | 213 |
| 14 | 234 | 144 | 206 |
| 15 | 255 | 122 | 183 |
| 16 | 255 | 101 | 150 |

Table 3

Reliability and Validity of Experiment 2.

|  |  |  |  |
| --- | --- | --- | --- |
| Participant | Paired-Comparison | Multi-Items Rearrangement | Validity |
| 1 | 0.96 | 0.92 | 0.96 |
| 2 | 0.94 | 0.85 | 0.91 |
| 3 | 0.89 | 0.89 | 0.90 |
| 4 | 0.93 | 0.86 | 0.93 |
| 5 | 0.94 | 0.89 | 0.95 |
| 6 | 0.98 | 0.83 | 0.93 |
| 7 | 0.97 | 0.95 | 0.97 |
| 8 | 0.99 | 0.84 | 0.96 |
| 9 | 0.70 | 0.79 | 0.77 |
| 10 | 0.93 | 0.83 | 0.93 |

Figures



Figure 1. The material used in the Experiment 1. The faces are constructed with four dimensions: the width between eyes, the height of eyes, the length of nose, and the position of mouth.

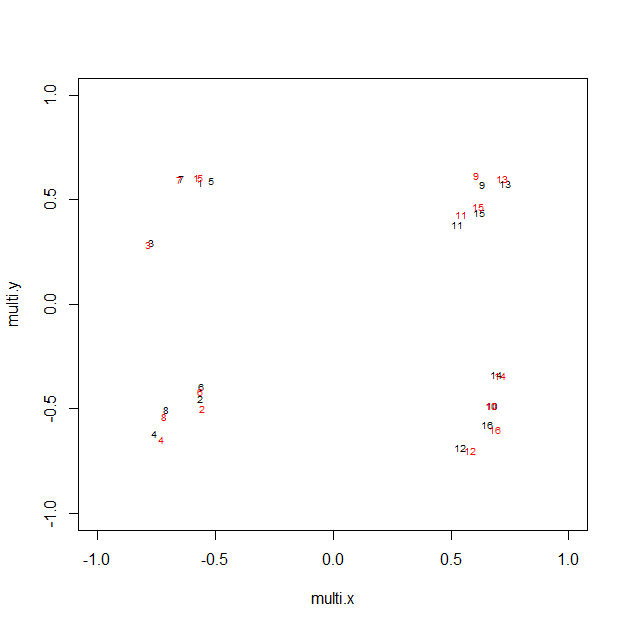


Figure 2. The MDS results of the similarity matrices acquired from the Multi-Items Rearrangement task and the Paired-Comparison task. The numbers indicate the items in Figure 1.



Figure 3. The material used in the Experiment 2. All the color patches are equality distributed on a color wheel which centers at set as 70, set as 20, and set as 38 with radius 60.

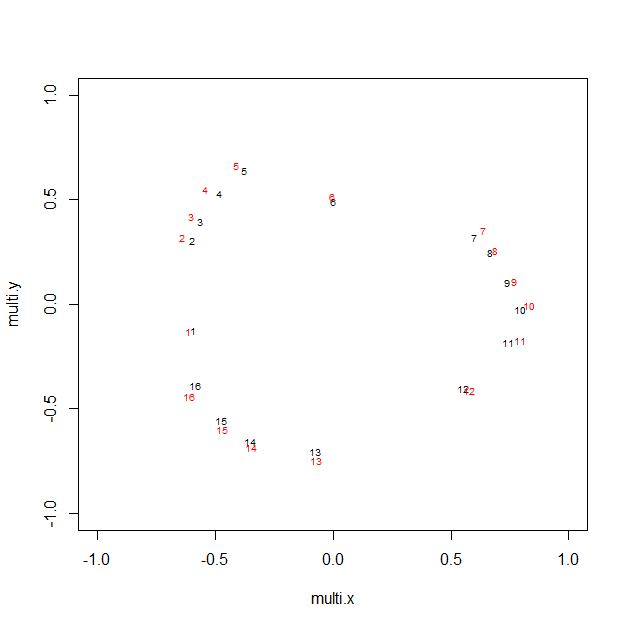


Figure 4. The MDS results of the similarity matrices acquired from the Multi-Items Rearrangement task and the Paired-Comparison task. The numbers indicate the items in Figure 3.