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The comparison of three methods of treating distance matrixes in semantic differential technique.

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Abstract

The purpose of this study was to compare three methods of treating distance matrixes in semantic differential technique using nine scales and forty paintings. They consisted of the correlation matrix converted from Euclidian distance, the city-block distance, and the Euclidian distance. The factor analysis of the correlation matrix resulted fairly well, and the MDSCAL solution of the city-block distance may be the best, but that of the Euclidian distance was difficult to interpret in spite of its minimum stress. Hence, the MDSCAL solution of Euclidian distance was undesirable, contrary to its popularity.

key words: paintings, semantic differential technique, Euclidian distance, city-block distance, factor analysis, MDSCAL.

Introduction

The present study were carried out to clarify the most effective treatment of two-way data of the semantic differential technique when factor analysis or multidimensional scaling was applied to the distance matrix. The d-method of factoring in stimulus space by Osgood, Suci, and Tannenbaum (1957) was based on the Euclidian distance, but it was not widely used as compared to the factor analysis which applied to the correlation matrix of SD scales.

Concerning Minkowski's parameter of distance, Attneave (1950) maintained that the psychological distance between stimuli was much greater than would be expected in Euclidian space but was approximately equal to the sum of the distance among fundamental dimensions. But, this city-block distance was not widely used. In applying MDSCAL (Kruskal 1964a, b) to the rated similarities, Arnord (1971) changed the parameter of MDSCAL and found that the best fitting model was the maximum component distance (the

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parameter=32), the second fitting model was city-block distance, and the worst was Euclidian distance. The important limitation of his technique was that it cannot be appled to the two-dimensional solution, and this reason was presently unknown (Shoben, 1983).

The technique of converson of Euclidian distance into coefficient of correlation was described by Mizuno (1974). When data matrix x_{ik} was standardized with means 0 and variance 1/N for each variable k, the Euclidian distance from the origin of multidimensional space to each variable k was $\Sigma x^2_{ik}=1$, and all the variables located at the surface on multidimensional sphere. When the distance of variable k to 1 was d_{kl}, and correlation was r_{kl}, then following formula was derived.

$$r_{ik}=1-d^2_{ik}/2$$

Applying factor analysis to the distance matrix was formally possible only when it was converted into correlation matrix. Another technique was the application of multidimensional scaling to the two-way distance matrix. The purpose of present analyses was to compare above three techniques of treating two-way distance matrix.

Method

Material. Forty paintings were randomly selected based on Ecrin's arts and monuments of the world (1981), as twenty paintings were from European and American, ten paintings were from Japanese, and ten paintings were from Chinese and Indian classical works. They were taken photographed colorly for slide projectors. Selected paintings were indicated in Table 1.

The rating scales Nine scales were selected from Isogai and Chiijiwa (1971), because the scales were high frequency words in the critics of paintings and they had large loadings in the factor analysis study. They consisted of dark-bright, faint-strong, decorative-simple, profound-frank, vivid-quiet, bold-delicate, strange-natural, human-material, and soft-hard.

Subjects Sixty four subjects participated. They were undergraduate students taking an introductory course in educational psychology.

Rating procedure The stimuli and subjects were randomly divided into two groups and the ratings of paintings were carried out separately by using a slide projector in each group. It took about forty minutes to finish this procedure.

The three analyses The Euclidian and city-block distance matrixes between stimuli were calculated on the standardrized scores with mean 0 and variance 1/N and the coefficient of correlation were derived by the method of Mizuno (1974). Then three matrixes were introduced. Firstly, the principal factor and geomax rotation method (Kashiwagi, 1965) were applied to the correlation matrix, secondly, MDSCAL were applied to the city-block and Euclidian distance matrixes. The Minkowski's parameter of MDSCAL was set to 1, since the preliminary analysis resulted lower stress. The correlation between dimensions and SD scales was calculated in each analysis, because it gave empirical data for interpreting the meaning of dimensions.

Table 1 The fourty works of painting used in this study.

1. Remnants of silk embroidery, with design of Tenjukoku Paradise, by unknown painter, A.C. 622, Japan.
2. First scroll, painted scroll of caricaturistic animals and human figures, by unknown painter, 12 century, Japan.
3. Portrait of Minamoto no Yoritomo, by Fujiwara Takanobu, 12 century, Japan.
4. Landscapes of the four seasons, by unknown painter, A.C. 1491, Japan.
5. Karashishi, by Kanou Eitoku, 16 century, Japan.
6. Pine trees, by Hasegawa Touhaku, 16 century, Japan.
7. A quil in autumn, by Tosa Mitsuoki and Tosa Mitsunari, A.C. 1685-91, Japan.
8. Secret love from the selected poems on love, by Kitagawa Utamaro, A.C. 1792-3, Japan.
9. Maiko girl, by Kuroda Seiki, A.C. 1893, Japan.
10. A salmon, by Takahashi Yuich, A.C. 1875-8, Japan.
11. A landscape in spring, by Chan Tzu Chien, 7 century, China.
12. Foreign guest (Mural of prince Chang-huai's tomb), by unknown painter, A.C. 711, China.
13. A night party of Han Hsi Tai, by Ku Hung Chung, 10 century, China.
14. Birds on judas tree with chrysanthemums, by Jue Chi, 14-17 century, China.
15. Magpies, by Hsue Pei Hung, A.C. 1948, China.
16. Reorganize the vagabonds, by Wang Shih Lang, A.C. 1947, China.
17. Landscape in the moonlight, by Kim Turyang, A.C. 1744, Korea.
18. A beautiful woman, by Sin Yunpok, 18 century, Korea.
19. A part of illustration of a Kalpasutra, by unknown painter, 15-16 century, India.
20. She who goes out to seek her beloved, by Unknown painter, 18 century, India.
21. Madonna del Magnificat, by Sandro Botticelli, A.C. 1483-5, Italy.
22. Venus of Urbino, by Tiziano Vecellio, A.C. 1538, Italy.
23. The vergin of the rocks, by Leonard da Vinci, A.C. 1506, Italy.
24. The portrait of a tailor, by Giambattista Moroni, A.C. 1570, Italy.
25. The avenue Middelharnis, by Meindert Hobbema, A.C. 1689, Holland.
26. Une baignade a Asnieres, by George Seurat, A.C. 1883-4, France.
27. The up-to-date marriage, by William Hogarth, A.C. 1743-5, England.
28. The death of Major Pearson, by John Singleton Copley, A.C. 1783, U.S.A.
29. Mrs. Macbeth with a dagger, by Henry Fuseli, A.C. 1812, Switzerland.
30. The lunchen of the boating party, by Auguste Renoir, A.C. 1881, France.
31. Nuit etoilee, by Vincent van Gogh, A.C. 1889, Holland.
32. Ia orana Maria, by Paul Gauguin, A.C. 1891, France.
33. La Japonaise, by Claude Monet, A.C. 1878, France.
34. Moi et le village, Marc Chagall, A.C. 1911, France.
35. Grandes baigneu ses, Paul Cezanne, A.C. 1898-1905, France.
36. Les trois musiciens, Pablo Picasso, France.
37. Broadway boogie woogie, by Piet Mondrian, A.C. 1942, Holland.
38. A girl and bird with the sun, by Joan Miro, A.C. 1942, Spain.
39. A large green vase, by Odilom Redon, A.C. 1910-2, America.
40. Armaments in December, by Roy Lichtenstein, A.C. 1968, America.

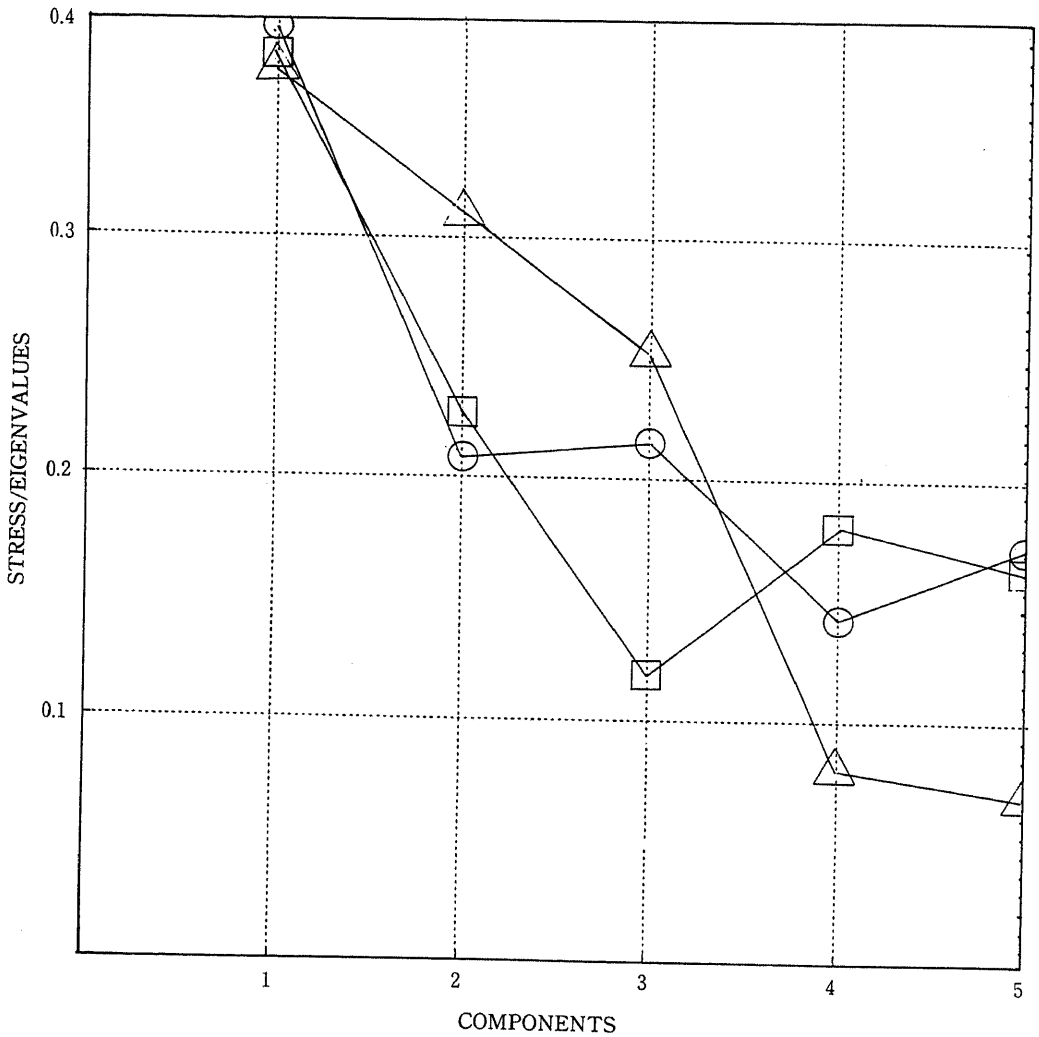

Fig. 1. The stress and eigenvalues (× 1/35) in the three analysis.
○—○ : stress in MDSCAL of city-block distance
□—□ : stress in MDSCAL of Euclidian distance
△—△ : eigenvalues in principal factor analysis.

Table 2 The three-factor solution by the principal factor and geomax rotation of the correlation matrix which was converted from Euclidian distance.

Stimuli	Factors 1	2	3	Stimuli	Factors 1	2	3
1	0.16	−0.28	0.86	21	0.82	−0.06	0.34
2	−0.41	−0.35	−0.59	22	0.80	−0.11	−0.45
3	0.17	−0.76	0.36	23	0.44	−0.56	0.39
4	−0.45	−0.88	0.09	24	0.33	−0.72	0.59
5	0.26	0.57	0.74	25	0.40	−0.78	−0.32
6	−0.80	−0.56	0.16	26	0.86	−0.17	−0.22
7	−0.04	−0.58	−0.70	27	0.87	0.08	0.32
8	0.25	0.02	−0.75	28	0.68	−0.11	0.67
9	0.55	−0.53	−0.46	29	−0.07	−0.31	0.82
10	−0.15	−0.56	0.39	30	0.82	0.06	−0.54
11	−0.42	−0.41	−0.79	31	−0.20	−0.00	0.89
12	−0.01	−0.70	0.53	32	0.82	0.25	0.14
13	0.68	−0.23	−0.36	33	0.83	0.44	0.20
14	0.33	−0.55	0.60	34	0.07	0.61	0.69
15	−0.52	−0.82	−0.07	35	0.70	−0.49	−0.41
16	0.70	−0.47	0.03	36	−0.16	0.68	0.65
17	−0.62	−0.53	−0.53	37	−0.51	0.85	0.06
18	−0.24	−0.67	−0.60	38	−0.52	0.51	0.22
19	0.23	0.44	0.76	39	0.53	0.27	−0.42
20	−0.03	−0.28	0.60	40	−0.12	0.87	0.47
Contr.					10.73	10.78	11.05

Table 3 The correlation between 3 factors and 9 SD scales

SD scales	Factors 1	2	3
1. dark-bright	0.31	0.52**	−0.58**
2. faint-strong	0.52**	0.44**	0.73**
3. decorative-simple	−0.47**	−0.68**	−0.54**
4. profound-frank	−0.46**	−0.17	−0.79**
5. vivid-quiet	−0.61**	−0.79**	−0.19
6. bold-delicate	−0.06	−0.78**	−0.43**
7. strange-natural	0.48**	−0.57**	−0.56**
8. human-material	−0.69**	0.34*	0.12
9. soft-hard	−0.47**	0.34*	0.64**

*……$p<.05$, **……$p<.01$

Result

The first analysis (factor analysis of correlations)

The eigenvalues of principal factor analysis of the correlation matrix converged as follows: 12.91, 10.83, 8.82, 2.80, 2.38. The sharp drop was observed between the third and fourth factor, as indicated in Fig. 1. Therefore, geomax rotation was applied to the three factor solution. The result of the rotation was indicated in Table 2, and the correlation between factors and SD scales were in Table 3.

The first factor had significant correlations with the scale of human-material (−0.69), and vivid-quiet (−0.61), etc. The positive end of this factor related closely to the No. 27, 26, 21, 30, 28, and No. 13 paintings, with which always contained human figures. Therefore, this factor concerned with "human-material".

The second factor had significant correlations with the scale of vivid-quiet (−0.79), bold -delicate (−0.78), decorative-simple (−0.68), strange-natural (−0.68), and dark-bright (0. 52), etc. The positive end of this axis related closely to the No. 40, 36, and No. 34 paintings, which were composed of vivid colors and bold lines, and the negative end related to the No. 3, 12, 18, 7, and No. 10 paintings, with which contained motionless persons or material painted by Japanese and Chinese artist. Therefore, this factor concerned with "vivid-quiet".

The third factor had significant correlations with the scale of profound-frank (−0.79), faint-strong (0.73), soft-hard (0.64), dark-bright (−0.58), etc. The positive end of this axis related to the No. 31, 1, 29, 34, 36, 20, and No. 12 paintings, which had realistic impressions, and the negative end related to the No. 8, 7, 18, and No. 11 paintings, which composed of simplified lines. Therefore, this factor concerned with "complex-simple".

The second analysis (MDSCAL of city-block distances)

The MDSCAL analysis of the city-block distance matrix started from five dimensions and the stress values resulted as follows; 0.39, 0.21, 0.22, 0.14, 0.17, and they were represented in Fig. 1. Therefore, two-dimensional solution was chosen, and indicated in Table 4. The correlations with the SD scales were indicated in Table 5.

The first dimension related significantly to the scales of faint-strong (.74), decorative-simple (−0.72), bold-delicate (−0.68), soft-hard (0.68), etc. The positive end of this dimension related to No. 37, 36, and No. 19 paintings, which gave complex and unrealistic impressions, and the negative end to No. 11, 2, 7, and No. 18 paintings, which gave simple impressions. Therefore, this dimension concerned with "complex-simple".

The second dimension related significantly to the scales of dark-bright (0.82), vivid-quiet (−0.79), etc. The positive end of this dimension related to No. 38 and No. 39 paintings, which gave dark impressions, and the negative end to No. 6, 4, and No. 10 paintings, which gave bright impressions. Therefore, this dimension concernd with "dark -bright".

Table 4 The two-dimensional MDSCAL solution of city-block distance matrix.

Stimuli	Dimension 1	Dimension 2	Stimuli	Dimension 1	Dimension 2
1	0.71	−0.47	21	0.36	0.23
2	−1.23	−0.17	22	−0.49	0.74
3	−0.13	−0.71	23	0.02	−0.35
4	−0.44	−1.00	24	0.07	−0.64
5	1.11	0.41	25	−0.67	−0.32
6	−0.21	−1.21	26	−0.37	0.62
7	−1.15	−0.29	27	0.43	0.35
8	−1.06	0.59	28	0.56	0.06
9	−0.85	0.26	29	0.67	−0.65
10	0.17	−0.96	30	−0.56	0.82
11	−1.31	−0.12	31	0.98	−0.57
12	0.12	−0.78	32	0.24	0.74
13	−0.53	0.58	33	0.42	0.75
14	0.33	−0.53	34	1.13	0.42
15	−0.77	−0.86	35	−0.67	0.30
16	−0.32	0.17	36	1.30	0.35
17	−1.20	−0.54	37	1.48	0.56
18	−1.12	−0.41	38	0.21	1.12
19	1.07	0.11	39	−0.22	1.17
20	0.65	−0.41	40	1.28	0.64

Table 5 The correlation between 2 dimensions and 9 SD scales

SD scales	Dimenstions 1	2
1. dark-bright	−0.16	0.82**
2. faint-strong	0.74**	0.25
3. decorative-simple	−0.72**	−0.50**
4. profound-frank	−0.64**	0.03
5. vivid-quiet	−0.52**	−0.79**
6. bold-delicate	−0.68**	−0.47**
7. strange-natural	−0.64**	−0.03
8. human-material	0.30	−0.10
9. soft-hard	0.68**	−0.23

*……$p<.05$, **……$p<.01$

Table 6 The three-dimensional MDSCAL solution of Euclidian distance matrix.

Stimuli	Dimension 1	2	3	Stimuli	Dimension 1	2	3
1	0.74	−0.35	−0.12	21	0.10	−0.32	0.78
2	−0.55	0.62	−0.68	22	−0.82	−0.13	0.60
3	−0.04	−0.73	−0.34	23	0.02	−0.54	−0.03
4	−0.02	−0.08	−1.09	24	0.16	−0.62	−0.24
5	1.00	0.12	0.54	25	−0.71	−0.31	−0.39
6	0.28	0.09	−1.17	26	−0.68	−0.21	0.53
7	−0.84	0.22	−0.65	27	0.09	−0.29	0.88
8	−1.11	0.35	0.12	28	0.33	−0.50	0.55
9	−0.96	−0.16	0.02	29	0.82	−0.14	−0.29
10	0.46	−0.46	−0.75	30	−0.81	−0.05	0.70
11	−0.65	0.45	−0.89	31	1.08	−0.03	−0.17
12	0.35	−0.41	−0.53	32	−0.17	0.10	0.84
13	−0.80	−0.37	0.41	33	0.12	0.15	0.96
14	0.22	−0.70	−0.11	34	0.97	0.33	0.41
15	−0.10	0.05	−1.06	35	−0.86	−0.21	0.16
16	−0.41	−0.57	0.25	36	1.04	0.45	0.33
17	−0.44	0.41	−1.02	37	0.52	1.16	0.31
18	−0.63	0.27	−0.81	38	0.59	0.96	0.08
19	0.92	0.17	0.47	39	−0.46	0.07	1.17
20	0.38	0.50	−0.17	40	0.88	0.68	0.42

Table 7 The correlation between 3 dimensions and 9 SD scales

SD scales	Dimensions 1	2	3
1. dark-bright	−0.44**	0.46**	0.52**
2. faint-strong	0.57**	−0.34*	0.64**
3. decorative-simple	−0.49**	−0.03	−0.76**
4. profound-frank	−0.57**	0.54**	−0.43**
5. vivid-quiet	−0.19	−0.14	−0.90**
6. bold-delicate	−0.55**	−0.38*	−0.49**
7. strange-natural	−0.76**	−0.57**	−0.01
8. human-material	0.43**	0.54**	−0.25
9. soft-hard	0.75**	0.20*	−0.11

The third analysis (MDSCAL of the Euclidian distance)

The MDSCAL analysis of the Euclidian distance matrix started from five dimension and the stress values resulted as follows; 0.38, 0.23, 0.12, 0.18, 0.16, and they were represented in Fig. 1. Therefore, three-dimensional solution was chosen, and indicated in Table 6. The correlation with the SD scales were indicated in Table 7.

The first dimension related significantly to the scales of strange-natural (−0.76), soft -hard (0.75), faint-strong (0.57), profound-frank (−0.57), etc. The positive end of this dimension related to No. 31, 5, 19, and No. 29 paintings, which were super-natural drawings, and the negative end to No. 9, 35, 22, and No. 30 paintings, in which contained natural portraits. Therefore, this dimension concerned with "strange-natural" or "hard-soft".

The second dimension related significantly to the scales of strange-natural (−0.57), profound-frank (0.54), human-material (0.54), etc. The negative end of this axis related to No. 3, 14, and No. 24 paintings, with which contained a natural portrait or landscape. Therefore, this dimension also concerned with "strange-natural" or "material-human".

The third dimension related significantly to the scales of vivid-quiet (−0.90), decorative -simple (−0.76), faint-strong (0.64), etc. The positive end of this dimension related to No. 33, 27, 32, and No. 21 paintings, with which contained human figures, and the negative end related to No. 6, 4, and No. 15 paintings, which were all landscapes. Therefore, this dimension concerned with "vivid-quiet".

Discussion

It was easy to determine the number of factors in the first analysis, because the sharp drop of eigenvalues was observed. The extracted three factors related to "human-material", "vivid-quiet", and "complex-simple" scales respectively, and these relations were confirmed by the factor loadings to the paintings. The first factor distinguished landscapes from portraits, the second bold paintings from quiet Oriental pictures, and the third realistic paintings from simplified one. It was also very easy to interpret the factors. Therefore, the conversion technique of Euclidian distance into correlations worked fairly well, but an extra dimension was introduced by this technique as compared to the second analysis.

The MDSCAL analysis of the city-block distance matrix resulted two-dimensional solution, for stress value was smaller than other solutions. The first dimension related to "complex-simple" and the second to "dark-bright" scales. The first one distinguished complex and unrealistic paintings from simple ones, and the second dark paintings from bright ones. It was easy to interpret the meanings of dimension in this analysis, and the number of dimension was more parsimonious than other analyses. Therefore, this analysis was superior to other techniques.

The MDSCAL of the Euclidian distance matrix resulted three-dimensional solution, for the stress values smallest then other solutions. The first dimension related to "strange-natural" and "hard-soft", the second to "strange-natural" and material-human", and the third to "vivid-quiet" scales. It was not easy to interpret the second one. The first dimension distinguished the super-natural drawings from natural portraits. The meaning

of the second dimension was unclear, although, the negative end concerned with both natural portraits and landscapes. The third related to "vivid-quiet" scales, and this distinguished portraits from landscapes. Therefore, this third analysis did not work well, for the second dimension was difficult to interpret.

In conclusion, the application of MDSCAL to city-block distances was the best way to handle two-way data of the semantic differential technique, because this technique brought about fewer dimensions which were easy to intepret. The application of factor ayalysis to the correlation matrix converted from Euclidian distances was also better, because the extracted factors by this technique was easy to interpret, though, more dimensions were introduced as compared with the MDSCAL solution of city-block distance. The MDSCAL analysis of Euclidian distances was undesirable, since it brought about more dimensions, which were not easy to interpret the meanings.

References

Arnord, J.B. 1971 A multidimensional scaling study of semantic distance. Journal of Experimental Psychology Monograph, 90, 349-372.

Attneave, F. 1950 Dimensions of similarity. American Journal of Psychology, 63, 516-556.

Ecrin's Arts and monuments of the world. 1981 Shufunotomo Co., Ltd.

Isogai, Y., & Chiijiwa, H. 1971 Psychological studies concerning the evaluations and appliciations of painting. Bulletin of the Musashino Art University, 13, 34-58.

Kashiwagi, S. 1965 Geometric vector orthogonal rotation in multiple-factor analysis. Psychometrika, 30, 4, 515-530.

Kruskal, J.B. 1964a Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychometrika, 29, 1-27.

Kruskal, J.B. 1964b Nonmetric multidimensional scaling: A numerical method. Psychometrika, 29, 115-129.

Mizuno, K. 1974 Cluster analysis. in Azuma, H. (Ed.) The methods in psychology, vol. 15. Data analysis II. University of Tokyo Press.

Osgood, C.E., Suci, G.J., & Tannenbaum, P.H. 1957 The measurement of meaning. Urbana: University of Illinois Press.

Shoben, E.J. 1983 Applications of multidimensional scaling in cognitive psychology. Applied Psychological Measurement, 7, 473-490.