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Multidimensional Scaling of Emotional Expression in Music

By Lage Wedin

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Among existing models for description of multivariate phenomena the *multidimensional* model has probably attracted the most frequent attention. In this connection factor analysis has been the dominating statistical technique. There are also several applications of this method in the field of musical perception (e.g. Gray & Wheeler, 1967; Henkin, 1955, 1957; Kötter, 1969; Nordenstreng, 1968, 1969 *a*; Wedin, 1969 *a*, 1969 *b*). However, factor analysis makes definite demands on the nature of data (interval level), which are not necessary within some multidimensional scaling models that have appeared recently. These methods make available for multidimensional analysis data collected under very moderate demands on the performance of the subject.

Green & Carmone (1969) have classified the *multidimensional scaling* models into three groups that sum up their main properties: (*a*) fully metric models, (*b*) fully nonmetric models and (*c*) nonmetric models. Common to all three is that for a given set of points (objects, individuals, tests, etc.) and some information about the interpoint distance (e.g. the subjective dissimilarity or similarity between pairs of points) they find the *dimensionality* and the *configuration* with different degrees of precision.

The *fully metric* models presuppose that the input data are originally ratio-scaled distances. Given a set of interpoint ratio distances, these methods solve the dimensionality and configuration of points whose distances (up to a positive additive constant) most closely match the input values themselves. Usually we would like to do this in the smallest possible number of dimensions for which the fit is satisfactory. Examples of applications of this method (Torgerson, 1958) of special interest in this connection, are an aesthetic study of artistic paintings (Skager et al., 1966) and a multidimensional scaling of emotions (Yoshida et al., 1970). The requirements of fully metric methods are rather severe, however, and there are certain problems in estimating the additivity constant, which makes alternative methods more attractive.

The *fully nonmetric* model as it is developed by Coombs, Bennet and Hays, the 'unfolding technique' (Coombs, 1964), requires as input only rank orders of interpoint distances, but it also yields only rank orders of points on each dimension as output. The most novel application of the unfolding technique is probably the derivation of stimulus configuration from order relations on pairs of pairs of points, e.g. preference data where the pairs of points are from different sets. All stimulus

points are ranked with regard to their distances from an ideal point—the representation of the individual's perfect preference. From an operational point of view later developments yield more from the same nonmetric input, namely metric output.

The *nonmetric* methods (Shepard, 1962 *a*, 1962 *b*; Kruskal, 1964 *a*, 1964 *b*; Torgerson, 1965) combine the best of both the earlier approaches giving metric solutions to rank order input data. Given a rank order of dissimilarities data, the nonmetric multidimensional scaling method finds a configuration whose rank order of (ratio scaled) distances best reproduces the original rank order of the input dissimilarities. The key to this type of solution is an iterative procedure made possible through the utilization of fast electronic computers.

Several computer programs have been written for this purpose. The one used in this study—TORSCA, written by Young and based on earlier work by Torgerson (Young & Torgerson, 1967; Young, 1968 *a*, 1968 *b*)—permits geometric representations in any Minkowski space and performs rotation in the Euclidean space.[1] Similarities as well as dissimilarities are accepted as input data, and the data matrix may be either a rectangular matrix or a symmetric matrix. In the former case it is assumed that the space to be derived is a joint space of both row and column variables—simultaneous unfolding of subjects and stimuli, for example. Thanks to the iterative technique the program successively searches for the configurations with the best possible fit as expressed by Kruskal's 'stress'.[2]

The present study is a complement to the factorial investigation published earlier in this journal (Wedin, 1969 *b*). The purpose is to illuminate the psychological nature of the perception of music and to compare the results of two different analytical techniques, factor analysis and nonmetric multidimensional scaling.

Method

This experiment was actually performed as a preliminary study to a semantic investigation of the perception of musical expression or musical 'meaning' (Wedin, 1969 *b*). The primary purpose was to obtain a basis for the selection of rating variables but it also guided the selection of stimuli. However, when it was found

[1] The distance between two points (i and j) in a metric space is defined

$$d_{ij} = \left[\sum_{s=1}^{t} (|i_s - j_s|)^r \right]^{1/r}$$

where i_s is the position of point i on dimension s and j_s is the position of point j on the same dimension; t = the dimensionality. The 'Minkowski-constant' (r), which indicates the type of distance to be calculated, may be given any value above or equal to 1.00; $r = 2.00$ gives a Euclidean space.

[2] The 'stress' is calculated by the formula

$$S = \sqrt{\frac{\sum (d_{ij} - \hat{d}_{ij})^2}{\sum d_{ij}^2}}$$

where d_{ij} is the distance between point i and j in the configuration and $\hat{d}_{ij}$ is the corresponding value from a sequence of numbers with a monotonic relation to the input data. The solution that minimizes this expression is taken to be the 'best' one.

that the preliminary experiment provided data for a basically different method of analysis, it was considered worthwhile to publish this study too. It presents an interesting comparison with—and a complement to—the metric factorial solution.

Experimental session

A sample of 35 musical excerpts was presented to 49 subjects (47 psychology students with little or moderate musical training and 2 music students), each subject being equipped with a list of 150 descriptive attributes. The subjects were asked to describe each piece of music with ten words from the list and/or from their own vocabulary. Each subject was allowed the time he needed but nevertheless some of the subjects did not manage to find all the ten words asked for. (This was utilized among other criteria in selecting the stimuli for the main experiment.) The whole experiment lasted 2 1/2 hours.

Descriptive attributes

Many dimensional studies of music and related stimulus continua have more or less directly applied the bipolar semantic differential scales (Osgood et al., 1957) primarily designed for more typical semantic studies (e.g. Jost, 1967; Kötter, 1969; Nordenstreng, 1969 *a*; Rahlfs, 1966; Solomon, 1958). In view of the preliminary character of this study, it was considered advantageous not to limit the sample of qualifiers by the assumption of bipolarity of perceptual dimensions but rather to let the analysis itself reveal the perceptual structure (some of the problems in this connection have been discussed by Nordenstreng, 1969 *b*) and further to use attributes specially selected to describe the domain of perceptual objects in question.

The attributes used in this experiment were 150 emotionally coloured adjectives, most of them used in a number of introspective-type studies on emotional content or 'abstract meaning' (Watson, 1942) in music (e.g. Hevner, 1936; Campbell, 1942; Watson, 1942; Farnsworth, 1954). Forty of those adjectives were then selected for further study. The selection was made (1) among the most frequently used words, which at the same time were among the 10 most frequent descriptions for at least one stimulus; (2) so that every one of the 28 primary clusters found in the list (Wedin, 1969 *b*) should be represented. A combination of those criteria excluded only two of the primary clusters, 'fiendish – diabolic' and 'incensed – angry'. These qualities—by Campbell (1942) designated 'cruelty'—are among those responses less often reported in studies of musical perception. The words included in the present analysis are presented in Table 4.

Stimuli

Thirty-five stimuli were included in the actual experiment, although only 20 of these were subjected to dimensional analysis for reason of comparability with the factor study in the main experiment. The musical stimuli, consisting of excerpts of 30–45 seconds duration, were selected chiefly from so-called 'serious' music partly of a programmatic nature. The general criteria for the first selection were: (1) wide dispersion in conceivably relevant musical factors such as instrumentation, style, tempo, rhythm, harmony, etc., (2) high intrastimulus homogeneity and

Table 1. The musical stimuli employed, with some frequent characteristics from the experiment.

No. Excerpt from	Some characteristics
1. Ravel: Bolero (E. Ansermet/L'Orchestre de la Suisse Romande)	emphatic, grand, triumphant, energetic, inspiring
2. Lidholm: Riter (Rites), Offerdans 2 (Sacrificial Dance 2) (S. Ehrling/The London Symphony Orchestra)	violent, wild, dramatic, vehement, raging
3. Tschaikowsky: Concerto for Piano and Orch. no. 1, Bb min. op. 23, Andante non con moto e molto maestoso. (G. Centini, Pi., R. Jones/Das Philharmonische Orchester)	grand, emphatic, majestic, proud, solemn
4. Ives, Charles: The unanswered question (L. Bernstein/New York Philharmonic)	doleful, serious, mournful, dark, melancholy
5. Grieg: Peer Gynt, Prelude op. 23 no. 1 (Ö. Fjelstad/The London Symphony Orchestra)	dreamy, peaceful, mild, lyrical, melancholy
6. Bach, J. S.: Christmas Oratorio, "Jauchzet frolocket auf, preiset die Tage" (H. Grischkat/Stuttgart Choral Society/The Suebian Symph. Orch.)	majestic, solemn, dignified, jubilant, sacral
7. Bach, Ph. E.: Sonata for flute and harpsichord, no. 6, G maj., Allegro (J.-P. Rampal, flute/R. Veyron-Lacroix, harpsichord)	light, lively, playful, glad, airy
8. Grieg: Peer Gynt, suite no. 1, In the hall of the mountain king. (See no. 5)	vehement, stormy, dramatic, furious, raging
9. Handel: Concerto Grosso, D maj., op. 6, no. 5, Largo (The Mozart Society Players)	pleasing, soft, peaceful, harmonious, gracious
10. Strauss, J.: Liebeslieder (W. Boskowsky/Vienna Philharmonic Orchestra)	inspiring, glad, happy, lively, exuberant
11. Buxtehude: Chorale, "Ach Herr mich armen Sünder" (J. Brenneke, organ)	religious, lofty, dignified, serious, tranquil
12. Alfvén: Symphony no. 4, C min., op. 39, Från havsbandet (G. af Malmborg, sopr., S.-E. Vikström, ten., N. Grevillius/Stockholm's Philharmonic Orch.)	impetuous, plaintive, melancholy, passionate, languishing
13. Chopin: Fantasie-Impromptu, C ♯ min., op. 66 (Käbi Laretei, piano)	playful, airy, exuberant, glad, lively
14. Ellington–Hackett: Sentimental Blues (Bobby Hackett)	relaxed, pleasing, harmonious, peaceful, calm
15. Debussy: Prélude a l'après-midi d'un faune (M. Rosenthal/Orch. du Théâtre National de l'opéra de Paris)	peaceful, mild, dreamy, delightful, romantic
16. Blomdahl: Chamber Concerto for piano, woodwind and percussion (H. Leygraf, piano, S. Ehrling/The London Symphony Orchestra)	uneasy, unrestrained, wild, agitated, violent
17. Honegger: Pacific 231. (See no. 1)	fateful, ghostly, uncanny, ominous, doleful
18. Grieg: Peer Gynt, suite no. 2, Ingrid's abduction and lament. (See no. 5)	serious, melancholy, heavy, tragic, dark
19. Rossini: La Boutique fantasque (ballet), Can Can (E. Ansermet/London Symphony Orchestra)	exuberant, lively, elated, emphatic, violent
20. Bach, J. S. – Swingle: Harpsichord Concerto, F min., Largo (Swingle Singers)	pleasing, relaxed, lovely, dreamy, friendly

(3) avoidance of direct semantic influence by choosing chiefly instrumental or non-verbal vocal music.

For practical reasons all 35 stimuli could not be included in the main experiment since every stimulus had to be rated on a great many rating scales. The reduction of the number of stimuli was based on a cluster of several criteria such as (1) inclusion of representatives of all main types of expression summarized by the clusters of the attribute list, (2) 'emotional richness'—the stimuli should easily be perceived and rated in subjective emotional terms by most of the subjects (this criterion was based on direct ratings of the degree of difficulty of ratings and also upon the total number of words that were elicited by each stimulus) and (3) each stimulus should be unequivocally perceived as representing a limited aspect of emotional expression. An index of homogeneity was thus calculated by utilizing the cluster structure of the word list, so that stimuli that could be described in terms of relatively independent clusters of attributes were excluded.

The stimuli finally selected for this study are presented in Table 1.

Results and discussion

Spearman rank correlations were calculated between all pairs of stimuli across attributes and between all attributes across stimuli in the total-frequency table, stimuli by words (20×40) (Tables 2 and 3). In the program TORSCA any off-diagonal values which are zero or negative are assumed to represent missing data. Therefore, 1.0 was added to the correlations to make them all positive. Multidimensional scaling according to TORSCA was then performed separately on those two similarity matrices.

Semantic space

For a three-dimensional solution (Euclidean space) the minimum stress is 'fair' (=0.072) while the four-dimensional solution has a 'good' fit (stress=0.048, see Kruskal, 1964*a*). There is practically no risk of getting such low stress values randomly with so many points and so few dimensions (Klahr, 1969)—in this respect both solutions are satisfactory. Although four dimensions give a better fit to our data, it may be argued that the lower stress in itself does not automatically indicate this solution, because the stress must necessarily decrease with increased dimensionality. The question is how many dimensions are necessary to get a satisfactory replication of the rank information in our input data. One way to solve this problem would be to search for an 'elbow' in the plot of stress vs. dimensionality, which would indicate a major decrease in the marginal improvement effected by an additional dimension. However, this is a question of economy. The costs of one computational run increase very rapidly with the number of points, so that only three and four dimensions could be extracted for the present study. Under these circumstances the purpose of comparison with the three-dimensional factor structure became the conclusive reason for choosing the three-dimensional solution. The reference axes were rotated to optimize the similarity with the varimax rotated factors (least square fit). This configuration is shown in Table 4.

Table 2. Spearman rank correlations between stimuli across 40 attributes.

Stimulus	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.56	.52	-.20	-.44	.31	-.29	.62	-.30	.25	-.41	.10	-.36	-.52	-.47	.43	.28	-.14	.49	-.52
2		-.10	-.19	-.67	-.21	-.40	.75	-.63	.00	-.72	-.31	-.34	-.66	-.65	.85	.48	-.54	.55	-.64
3			.01	.09	.63	.03	.28	.25	.33	.18	.36	-.17	-.14	-.05	-.25	.04	.18	.22	-.08
4				.39	-.05	-.04	-.08	.37	-.56	.35	.34	.01	.46	.40	-.09	.51	.54	-.47	.16
5					.02	.30	-.52	.64	-.15	.64	.35	.33	.78	.73	-.67	-.25	.49	-.52	.71
6						.07	.02	.35	.17	.36	.33	-.09	-.12	-.06	-.29	.00	.05	.03	-.09
7							-.44	.21	.43	.01	-.19	.82	.38	.31	-.24	-.40	-.19	.19	.43
8								-.42	.02	-.49	-.10	-.44	-.59	-.61	.65	.53	-.26	.44	-.61
9									-.19	.73	.40	.12	.60	.65	-.63	-.21	.43	-.42	.47
10										-.38	-.27	.46	-.22	-.17	-.05	-.44	-.51	.60	.12
11											.52	-.13	.47	.51	-.75	-.17	.68	-.67	.39
12												-.27	.26	.29	-.30	.15	.61	-.41	.19
13													.42	.33	-.16	-.39	-.26	.18	.54
14														.87	-.46	-.22	.36	-.59	.76
15															-.55	-.27	.37	-.50	.79
16																.45	-.53	.46	-.62
17																	.17	.01	-.46
18																		-.69	.22
19																			-.41

The first dimension is clearly bipolar—positively characterized by attributes such as vehement, warlike, unrestrained, violent, furious, stormy and wild, and negatively by soft, mild, relaxed, pleasing, dreamy and peaceful. It has to do with tension, energy and intensity in the musical expression and will be summarily designated *Tension/Energy.*

The second dimension, also bipolar, stands for light – dark, happy – sad moods such as playful – doleful, glad – sad. The negative pole may also include moments of threat or repulsion. Therefore this is not purely happiness – sorrow but rather something like attraction – rejection. Dimension II which has been designated *Gaiety – Gloom* is typically represented by such words as playful, airy, exuberant, glad versus doleful, serious, ghostly, unhappy and fateful.

The third dimension is primarily characterized by a few high and moderately high positive values—majestic, solemn, sublime, grand and religious. There is only one extremely negative and a few moderately negative values—strange and uneasy, unhappy, ghostly, seductive. The bipolarity does not seem to make much sense in this case (cf. interpretation of factors, Wedin, 1969 *b*). We will leave the problem of bipolarity for further study and consider the positive values as representing the dominating character of the third dimension, which will be designated *Solemnity.*

Stimulus mapping

For reasons similar to those already given, a three-dimensional solution was considered to be the most interesting (minimum stress was achieved = 0.035 which may be characterized as a 'good' fit). Rotation was performed to a least square fit with the Q-factor matrix (Wedin, 1969 *b*). The rotated configuration is shown in Table 5.

The first dimension is positively characterized by excerpts 2 (Lidholm), 16 (Blomdahl), 8 (Grieg: Mountain King), 19 (Rossini) and 1 (Ravel). Common to these stimuli is the expression of energy, intensity, tension, power and similar energy-related qualities. Although the interpretation cannot be made as straightforward in this case as in the semantic space, the experimentally most frequent characterizations will corroborate this conclusion. Attributes such as violent, wild, vehement, powerful, energetic, agitated are among the most frequently selected ones for these stimuli.

The negative pole of this dimension is characterized by excerpts 11 (Buxtehude), 5 (Grieg: Prelude), 9 (Handel), 15 (Debussy), 20 (Swingle Singers) and 14 (Ellington). The most prominent qualities common to these stimuli are relaxation, softness, gentleness, tenderness and the like. Among the most frequently selected attributes are peaceful, mild, relaxed, dreamy, soft, pleasing. This dimension will be summarily designated *Tension/Energy.*

The second dimension will be labelled *Gaiety – Gloom* to indicate the qualities expressed by excerpts 10 (Strauss), 7 (Bach, Ph. E.), 13 (Chopin) and in some degree 19 (Rossini) on the one hand, versus excerpts 18 (Grieg: Ingrid's lament), 17 (Honegger), 12 (Alfvén) and 4 (Ives) on the other hand. What characterizes these stimuli is primarily exuberance, happiness and liveliness versus gloominess, depression and darkness. The most conspicuous perceptual qualities are the impres-

Table 3. Spearman rank correlations between attributes across 20 musical stimuli (decimal points omitted)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	23	11	33	77	−48	−30	−65	21	−20	34	−65	40	−26	20	64	−66	43	−48	20	−26	−28	51	−34	−68	−42	28	51	−50	−58	70	19	−51	−33	17	−04	−72	54	72	−53
2		89	75	19	−78	−66	26	04	59	−17	−44	82	−47	−49	17	−08	72	−85	−48	35	27	08	−81	−44	36	85	−08	−73	−61	35	−30	−67	−52	34	−19	−50	22	53	−67
3			69	00	−74	−58	33	−02	74	−19	−36	88	−56	−44	16	−07	65	−73	−65	39	44	04	−78	−34	50	76	−16	−71	−66	20	−51	−68	−47	44	−37	−46	24	44	−68
4				29	−69	−61	−01	26	38	−10	−42	81	−47	−32	18	−26	81	−76	−17	41	02	12	−73	−64	19	81	10	−75	−62	60	−30	−72	−52	70	−28	−50	23	81	−74
5					−28	−21	−53	12	−33	19	−65	26	03	13	21	−67	41	−35	41	−29	−48	45	−25	−65	−49	24	45	−35	−43	57	34	−32	−31	14	17	−56	43	60	−39
6						75	−04	04	−56	10	49	−80	48	36	−46	17	−69	92	50	−35	−33	−18	76	47	−35	−78	−04	82	81	−56	30	86	58	−34	14	56	−46	−65	68
7							−10	18	−30	52	52	−63	39	69	−17	14	−78	86	32	−29	−09	22	66	46	−10	−84	−24	70	57	−47	−06	87	85	−40	05	41	−06	−64	64
8								−12	66	−28	49	−02	−14	−35	−43	66	−19	−09	−43	53	60	−37	−25	59	75	04	−26	−03	03	−50	−50	07	15	−04	−11	35	−28	−39	00
9									−07	37	−01	08	−04	23	25	−23	−02	09	28	36	−28	25	05	−22	−21	−13	08	−20	04	33	−08	02	24	43	−13	−16	19	25	−09
10										−11	15	47	−41	−27	00	41	17	−51	−72	57	84	05	−65	20	89	35	−40	−49	−55	−06	−70	−38	02	22	−37	−08	18	02	−49
11											20	−15	−34	88	43	−23	−24	24	15	−10	00	71	03	−01	−11	−34	−03	−02	−01	08	−17	25	48	06	−34	−18	55	01	−05
12												−59	−05	32	−38	76	−68	51	−09	13	40	−20	26	85	45	−58	−24	40	45	−47	−38	61	71	−21	−06	71	−28	−62	43
13													−46	−39	36	−35	85	−78	−45	20	16	20	−71	−60	22	85	09	−74	−66	48	−36	−78	−59	48	−35	−58	42	74	−68
14														−16	−33	−01	−39	47	38	−17	−42	−21	69	17	−35	−44	02	70	49	−26	45	47	26	−53	62	41	−36	−41	66
15															26	−10	−41	50	31	−27	−06	57	31	07	−16	−57	−16	23	17	−03	−11	45	57	02	−34	−02	38	−17	17
16																−32	31	−29	−14	07	02	63	−18	−46	−20	17	08	−32	−37	51	−11	−45	−21	23	−30	−35	63	43	−32
17																	−42	15	−25	26	59	−31	03	69	65	−25	−45	24	21	−40	−38	30	36	−22	−02	65	−36	−54	26
18																		−78	−24	14	−12	15	−64	−74	−08	92	22	−67	−53	64	−01	−79	−77	55	−27	−55	29	86	−65
19																			38	−31	−25	−08	87	51	−28	−86	−21	81	81	−58	16	88	66	−35	11	55	−27	−73	79
20																				−38	−62	06	42	−21	−59	−34	28	32	32	05	62	35	07	−10	19	−08	−18	04	24
21																					26	−12	−31	00	39	18	−20	−27	−30	12	−38	−34	−09	52	−04	13	−10	07	−26
22																						08	−47	48	91	08	−43	−28	−36	−17	−61	−08	23	−04	−42	06	13	−23	−25
23																							−23	−23	−10	−03	−06	−25	−31	36	−17	−10	21	18	−41	−25	82	29	−33
24																								31	−47	−73	−11	85	82	−45	36	70	40	−44	34	50	−32	−61	89
25																									46	−58	−19	47	48	−66	−23	63	68	−54	11	69	−28	−78	53
26																										17	−47	−29	−31	−26	−74	−09	20	02	−34	12	03	−21	−23
27																											08	−72	−53	44	−09	−79	−78	41	−22	−55	21	71	−64
28																												−06	−13	35	33	−21	−22	−09	27	−18	−05	48	−16
29																													78	−59	30	79	48	−61	35	63	−51	−71	85
30																														−57	27	77	42	−42	17	58	−39	−62	85
31																															13	−54	−37	49	−06	−50	32	83	−50
32																																15	−28	−29	46	−14	−33	03	28
33																																	78	−54	18	50	−38	−76	80
34																																		−36	00	47	−01	−60	46
35																																			−49	−29	24	58	−62
36																																				29	−42	−24	42
37																																					−34	−64	59
38																																						40	−43
39																																							−71

sion of fast vs. slow motion and a high vs. low pitch. This is certainly true of nos. 7, 13 and 17, 18. No. 4 (Ives) is also extremely stagnant and somewhat dissonant. Excerpts 10 and 19, in addition to being fast and active, are also powerful and vivacious, which in combination seems to give the impression of a more violent happiness or exaltation. It may be noticed in passing that the word list (in Swedish) showed two separate clusters for those qualities: gay – glad and exuberant – elevated. Watson (1942) also distinguishes between happy – glad and very happy – exuberant. Frequently selected attributes are playful, light, exuberant, glad, lively versus doleful, fateful, serious, sad and unhappy.

The third dimension has two high values and one moderately high (positive) value—excerpts 6 (Bach, J. S.), 3 (Tschaikowsky) and 1 (Ravel). These stimuli are characterized as powerful, grand, solemn, majestic. In comparison with the (only

Table 4. Configuration (semantic) rotated to hypothesis matrix (i.e. factor matrix, varimax rotated).

Attribute	Dimension I	II	III
1. Serious	−.34	−.56	.18
2. Relaxed	−.68	.07	−.15
3. Pleasing	−.68	.18	−.06
4. Dreamy	−.67	−.12	−.02
5. Doleful	−.24	−.62	.03
6. Vehement	.67	.02	.00
7. Powerful	.57	.08	.22
8. Playful	−.11	.60	−.25
9. Impetuous	−.01	−.29	.28
10. Light	−.45	.49	.02
11. Majestic	.13	−.08	.55
12. Inspiring	.35	.50	.04
13. Soft	−.70	−.06	−.05
14. Uneasy	.49	−.16	−.41
15. Grand	.31	−.08	.49
16. Religious	−.33	−.32	.45
17. Exuberant	.16	.60	−.18
18. Peaceful	−.67	−.25	−.14
19. Violent	.65	.05	.06
20. Fateful	.38	−.50	−.01
21. Seductive	−.37	.35	−.31
22. Glad	−.25	.59	.13
23. Solemn	−.15	−.17	.54
24. Warlike	.66	−.10	−.11
25. Lively	.39	.51	−.08
26. Airy	−.26	.60	.01
27. Mild	−.69	−.11	−.21
28. Unhappy	−.11	−.54	−.34
29. Unrestrained	.66	.04	−.14
30. Furious	.64	.07	−.16
31. Sad	−.47	−.46	.02
32. Ghostly	.29	−.55	−.32
33. Stormy	.62	.16	.04
34. Triumphant	.43	.28	.24
35. Yearning	−.58	−.01	.27
36. Strange	.25	−.18	−.60
37. Agitated	.42	.37	−.29
38. Sublime	−.35	−.11	.50
39. Melancholy	−.60	−.38	.01
40. Wild	.62	.08	−.23

moderately) negatively loaded excerpts (nos. 4, 14, 13, 15, 20), the most salient qualities of this dimension appear to be pomposity, stateliness, powerfulness and *Solemnity.*

Table 5. Configuration (stimulus mapping) rotated to hypothesis matrix (i.e. Q-factor matrix, varimax rotated).

Excerpt	Dimension I	II	III
1. Ravel	.58	−.07	.36
2. Lidholm	.83	−.08	−.08
3. Tschaikowsky	.11	.01	.53
4. Ives	−.14	−.43	−.36
5. Grieg: Prelude	−.56	−.01	−.14
6. Bach, J. S.	−.07	.04	.59
7. Bach, Ph. E.	−.15	.58	−.18
8. Grieg: Hall of Mountain King	.71	−.17	.10
9. Handel	−.55	−.05	.11
10. Strauss	.23	.65	.19
11. Buxtehude	−.58	−.24	.13
12. Alfvén	−.23	−.45	.25
13. Chopin	−.13	.55	−.32
14. Ellington	−.49	.04	−.35
15. Debussy	−.53	.03	−.29
16. Blomdahl	.78	−.05	−.22
17. Honegger	.44	−.50	−.18
18. Grieg: Ingrid's lament	−.38	−.51	.02
19. Rossini	.64	.40	.09
20. Swingle Singers	−.52	.25	−.26

Comparing the factorial solution with nonmetric multidimensional scaling

Even a superficial examination will show that there is an extremely good agreement between the results of factor analysis of quantitative ratings (Wedin, 1969 *b*) and the nonmetric multidimensional solution based upon qualitative verbal description. Tables 6 and 7 show a correlational study of the relation between the different analyses. The diagonal correlations are extremely high. Among the off-diagonal correlations a slightly positive covariation may be noticed between the first factor and the third dimension (loadings)—and vice versa—of the stimulus space. A corresponding correlation is not found in the semantic space. This suggests a certain relationship between the musical expressions of tension, energy and stateliness, solemnity, although the corresponding semantic correlates may be unrelated. This effect was also found in the factorial study. It might be an effect of the relative limitation of the stimulus selection, but it might also indicate that the more consistently perceivable qualities of musical expression in fact are quite few. Obviously in the extreme case with a perfect correlation between the loadings of two dimensions, only one dimension would be needed to account for the structure. ('Consistently perceivable qualities' here refers to reliably verbalized or otherwise reliably and consistently communicated descriptions of the music as it is perceived in different contexts.)

Table 6. Product-moment correlations between semantic 'dimensions' from nonmetric multidimensional scaling and sematic 'factors' from factor analysis of quantitative ratings.

	Dimension		
Factor	I	II	III
I	.97	.15	−.08
II	.14	.96	−.08
III	−.09	−.10	.89

Table 7. Comparison between stimulus mapping and Q-factor analysis. Product-moment correlations between 'dimensions' and 'factors'.

	Dimension		
Factor	I	II	III
I	.97	.09	.24
II	.08	.97	−.03
III	.31	−.06	.96

General comments

The comparison between the approaches of factor analysis and nonmetric multidimensional scaling may give rise to some general conclusions. First, it seems encouraging that the main outcome—the basic structure of the perception of musical expression—reappears so unaltered as a result of such different approaches. Since the rating technique, the method of analysis and the subjects involved are different, this has a certain validative power, psychologically as well as methodologically. At least it offers a reason to reflect on the use of statistical techniques that demand interval or ratio data. Nonmetric scaling seems to be a powerful alternative.

It should be noticed that although the TORSCA analysis gives results equivalent to those of factor analysis, the subject is faced with a much less artificial and difficult rating situation when the former method is used. For one thing, the subject need not quantify his responses but is allowed to act very much as he often does any time he listens to the radio or visits the concert hall, expressing his experience and opinion in self-selected verbal terms. This also means that the subject is not forced to judge stimuli—as he is in semantic differential studies—on a lot of scales, some of which are quite irrelevant to the piece in question or meaningless to the subject. Thus in some respects the rating situation applied here may be regarded as less exacting. The moderate demands on scale level reduce the risk of overestimating the subject's ability to carry out the experimental instruction. After all, in this study we are concerned with extremely complex aesthetic stimuli and not with weights or circle areas.

A general advantage of this type of nonmetric scaling is that the procedure permits a less restricted material than does a conventional semantic differential study.

Above all, the method does not demand so many arbitrary restrictive interferences from the experimenter. In general it should be regarded as desirable that experimental situations and methods of measurement involve a minimum of artificial restrictions on the subject's everyday functions of perception. In this respect the nonmetric scaling according to Kruskal, Shepard, Torgerson, Young among several others, seems a promising alternative for the purpose of multidimensional analysis.

One drawback to the present technique of deriving measures of similarity (or distances) should be mentioned. Because of the procedure of calculating rank correlations based on frequencies in the total subject sample, we have to assume that the result is general across all subjects. In spite of some results showing a high intergroup consistency in this special study (Wedin, 1969 *b*) this is a very grave assumption in general—especially if one is forced to make it. Of course there are ways around this assumption as in factor analysis, where single individuals may be studied. But if single individuals are to be studied, some of the advantages of the nonmetric method become more doubtful. The subject's task would then be to *rank* all attributes according to their distances to every single stimulus with as few ties as possible. And this might be as difficult as any quantification.

Some further musicological and psychological implications

Several questions probably arise when one tries to 'understand' what 'really' comes out of this study (including the previous paper on factor analysis).

What really is the status of the dimensions or factors arrived at? Do they 'exist' in any manifest sense as fundamental perceptual qualities, or are they more or less a piece of statistical hotchpotch? What in fact do they measure? If we leave the special problems connected with determining the dimensionality, avoiding nonsense factors and similar statistical problems, we still have the problem of deciding on the psychological or musical 'meaning' or 'nature' of the factors.

First, it should be obvious that the dimensions reflect the contents of *psychological responses* to music—or more exactly: the process of matching between 'semantic meaning' and 'musical expression'—rather than the qualities of the musical stimuli themselves. This is evident from the fact that the listeners themselves have been used as 'instruments' in the process of measurement. The 'units' of response have been verbal attributes used to describe perceptual qualities. Although the subjects were instructed to judge 'the music', their responses must be regarded as manifestations of subjective experience of the musical stimuli. In this respect the factors might be said to exist within the listener himself. That is *not* to say that the dimensions have any 'fundamental' status implying that the subject's responses are built up or derived from this conceptual framework. What may be said is that a great deal of variation in experience can be reproduced by these extracted dimensions. They constitute an economical descriptive system.

However, several 'levels' of the process of perception may be identified—from what we would call purely perceptual and immediately affective through more complex cognitive or representational levels (see Nordenstreng, 1969 *b* and Osgood, 1963). This study was originally intended to deal with emotional qualities in music,

with a view to establishing some kind of descriptive and differential system. The selection of attributes therefore excluded purely private affectively evaluative attributes. The main contents of the factors therefore seem to be *perceptual* and (in a limited sense) *affective-emotional* qualities. Even if higher-level representational attributes are exemplified (in words like impetuous, seductive or sublime), such attributes are few as a result of the selection procedure, and there are also indications that those qualities are less reliably perceived than more 'simple' perceptual or emotional qualities (such as lively, wild and peaceful, soft). This is in accordance with the opinion that the 'meaning' of music (if any) should be mainly 'affective' rather than 'denotative' in character (Osgood et al., 1957).

A natural question now would be: do there exist any definable musico-technical correlates (i.e. independent stimulus variables) to those perceptual-emotional qualities? We only touched on this question in connection with the interpretation of the dimensions. This is actually a problem to be solved by musicologists. Very tentatively it might at present be suggested that the tension-factor is related to dynamics (volume), dissonant-consonant harmonies and maybe the degree of rhythmic complexity, while the gaiety-gloom-factor more is related to tempo, pitch and modality (for example major or minor).

Another crucial question is that of the generality of the results—more specifically formulated: to what degree are the results repeatable—when using different methods of rating and analysis of data and in independent investigations? Do the same factors appear for different samples of music, different subjects and for different (equivalent) sets of rating scales? It must be stressed that the outcome of a factorial study is extremely dependent on the material included (which makes the selection procedure very important). A serious lack of generality has been shown to be caused by interactions between stimuli and rating scales—the exact meaning of some attributes changes somewhat from stimulus to stimulus (see Osgood, 1962; Nordenstreng, 1969 *b*). Our data show clear dissimilarities between correlation matrices for different single stimuli (correlations calculated between rating scales across individuals, quantitative ratings). This means that the factor structure will not be general across single stimuli. The significance of this interaction is to be studied further. It is not impossible that there may also exist interaction effects between stimuli/rating scales and individuals.

We have already seen that the structure reappears for the same stimuli and attributes as a result of different methods and in different subject samples. It would now be interesting to try a quite different *non*-semantic approach, for instance the more 'holistic' similarity analysis (the subjects directly estimate the subjective similarity, Nordenstreng, 1968). The present investigation might be accused of excessive dependence on *semantic* comprehension and of being less reflective of *musical* perception.

As to the question of generality, it may be mentioned that further research on a slightly broader stimulus material (40 stimuli, 125 attributes) so far corroborates the earlier findings (the results will be published in due course). More detailed individual studies are also being performed.

Another source of comparison would be other independent studies focusing on the same problem. I know of three such studies at present and these are somewhat encouraging. In the first of these studies, Nordenstreng (1969 *a*) found five factors in a semantic differential study on music (and speech). The first and the third factor—*Softness* and *Relaxation*—together seem to contain about the same as our first factor, *Tension/Energy* (resting – busy, exciting – calming and tense – relaxed, violent – gentle). The second factor is labelled *Colourfulness* and "represents musical richness as opposed to monotonous emptiness". It is very much an activity-factor and corresponds to our second factor, *Gaiety – Gloom.* The fourth factor, called *Magnitude* (masculine, powerful), may be seen to have some relation to our *Solemnity* (grand, majestic).

The second interesting study (Kötter, 1969) gave four factors. They were designated (in German) *Dynamik, Gefühl, Trivialmusik* and *tänzerisch-geistische Musik.* Only the first and the third factor are recognized as being related to our results. Most interesting is the *Trivialmusik*-factor (named by its negative pole). It seems to be a close equivalent to our *Solemnity*-factor. It is (positively) described as representing 'gehobene' and 'ernste' music, and two of the most positively loaded stimuli are probably identical to our stimuli 1 and 3 (Ravel: Bolero, theme with full orchestra and Tschaikowsky: Piano Concerto, Maestoso, opening).

The third study is a Finnish one using 48 stimuli rated on 25 semantic scales (Seppälä, 1968). Five factors emerged. The two first factors are most important for a comparison here. Since the verbal interpretations are not very revealing, we will confine ourselves to the highest loaded scales. They are for the first factor sad – gay, depressed – eager, happy – unhappy, elastic – stiff, anxiety producing – anxiety releasing and active – passive. It is not difficult to see the close relation to our second factor *Gaiety – Gloom.* Among the high loadings on the second factor of the Seppälä study are beautiful – ugly, harmonious – dissonant, hard – soft and pleasant – unpleasant. The scales are mostly different, but the content is partly identical to our *Tension/Energy.*

Clearly, the verbal interpretations of factors may be rather arbitrary, and consequently they should not be taken too seriously. Still it seems as though behind the different labels there may be distinguished at least two qualities that are more prominent and more fundamental than others to musical expression. Perhaps the old theory of musical expressiveness suggested by Ferguson (see Hevner, 1935 p. 202) may provide a frame of reference for the common traits found in the different studies referred to. "For him there are two kinds of elements basic for all music, 'motion suggestion' and 'stress suggestion'. The first of these carried by the tempo and rhythm is the tendency toward movement, the impulse to follow the activity of the music..." (cf. the second factor of the present study (see also Wedin, 1969 *b*), the fourth factor of Kötter, 1969 and the first factor of Seppälä, 1968). The 'stress suggestion' is defined as "a matter of intensities and extensities of response, of tensions and relaxations, of efforts and restraints" (cf. the first factor of the present study (see also Wedin, 1969 *b*), the first and third factor of Nordenstreng, 1969 *a,* the first factor of Kötter, 1969 and the second factor of Seppälä, 1968).

Summary

Twenty musical excerpts were judged qualitatively in terms of emotionally descriptive adjectives, which the subjects selected from a list of 150 words and from their own vocabulary. Rank correlations were calculated (*a*) between 40 of the most frequently used adjectives across stimuli and (*b*) between all stimuli across the same 40 adjectives. The calculations were based on the total frequencies in a sample of 49 subjects. Nonmetric multidimensional scaling was then applied. Three dimensions were extracted and labelled: *Tension/Energy, Gaiety – Gloom* and *Solemnity.* The structure was found to be practically identical to the results emerging from a corresponding factor analysis.

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