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THE CONNOTATION OF MUSICAL CONSONANCE

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Musical intervals can be judged in many ways; they may be experienced as "soft", or "sharp", or "beautiful", "complex", "high", "loud" and so on. "Consonant" and its opposite "dissonant" belong to the list of subjective characteristics of chords, but it is not at once clear how this dimension of judgment is related to the other ones. It might be that "consonant—dissonant" is in a way a basic dimension; on the other hand it can not be excluded a priori that consonance would be an amalgamation of other fundamental categories.

Some knowledge about the location of the dimension "consonant—dissonant" in the space of meanings which can be attached to chords would be helpful for any research on consonance. The alternative objective of psychological and physiological studies of consonance is, of course, to relate the experience of consonance to measurable characteristics of combinations of tones (4). But the question as to what subjects *mean* by this qualification of chords as consonant or dissonant is then a preliminary one.

There are several techniques to investigate the relationships between judgmental categories. Some of these techniques, as the method of triadic comparison (7), are non-verbal, but this advantage is always coupled with the disadvantage that these techniques are very time-consuming and therefore a burden to experimenter and subjects. For the study, to be described here, a verbal technique has been chosen: Osgood's method of the semantic differential (3). The obvious disadvantage is then, that the experience of subjects is moulded into a *restricted* number of *verbal* categories—on the other hand the method has been proved useful in a diversity of situations and it is also a rather quick one.

METHOD

The general procedure followed in this experiment was that subjects had to judge musical intervals of two pure (sine) tones against ten

semantic scales. These scales are given in table 1. Among them is the scale consonant—dissonant; the other scales were selected in view of the literature concerning consonance and the semantic differential.

Apparatus and material

To compose the different intervals an apparatus was used which produced a series of pure tones with fixed frequency ratios. This apparatus consists of an electromotor with number of revolutions per second equal to the frequency of the supply current. On the shaft 16 "tone wheels" are fixed with a number of teeth of 2n, where $n = 1, 2, 3 \ldots 16$. With these wheels in a capacitive way electrical periodical signals are produced with frequencies $2n$ times the frequency of the supply current.

To get pure sinusoïdal tones electrical filters in each of these 16 channels were necessary, for which purpose non variable bandpass filters were used. In consequence of this fact only a series of tones of fixed frequency can be produced. For this series frequencies $n \times 85$ cps. were taken, so the motor is driven by a current with a frequency of 42.5 cps.

With this apparatus each combination of tones with frequencies of 85, 170, 255, ... 1360 cps. can be chosen. The advantage of this method is that for each tone combination the frequency ratios are mathematically true. For this investigation only combinations of two tones were used.

All intervals with ratios between 1 : 2, 2 : 3 and 15 : 16 can be given, but it appears that as the ratio is more simple, the height defined as the average of the two frequencies can be chosen more freely.

For instance for an octave we can take 1 : 2, 2 : 4, 3 : 6, 4 : 8, 5 : 10, 6 : 12, 7 : 14 and 8 : 16 (each number multiplied by 85 cps.), whereas the minor third can only be composed as 5 : 6 or 10 : 12. This means that it is impossible to have the same height for all intervals. For the experiments all ratios within the octave with numbers from 1 to 12 were used, 23 in total. It was tried to use intervals with heights as nearly to each other as possible. This led to the tone combinations given in table 1. Multiplying these numbers by 85 gives the real frequencies.

These 23 intervals include all important musical intervals within the octave: octave (1 : 2), fifth (2 : 3), fourth (3 : 4), major third (4 : 5), major sixth (3 : 5), minor third (5 : 6), tritonus (5 : 7), minor sixth (5 : 8), major seconds (8 : 9, 9 : 10), minor seventh (5 : 9), major seventh (8 : 15), and minor second (15 : 16).

The intervals were reproduced by a loudspeaker. The subject was sitting in front of it in a sound proof room with absorbing walls. The sound pressure level of the tones was about 70 db.

Subjects and procedure

Ten intelligent subjects (all layman where music is concerned) participated in the experiment. They were tested individually.

To accustom them to the sounds, the 23 intervals were first presented without rating instructions. After this habituation series the series of intervals was presented another time and the subject was asked to rate each

TABLE 1

Judgement of 23 intervals against 10 scales. Sum of scores of 10 subjects. For every scale the left alternative is given the value 7, the right the value 1.

	5/10	6/9	6/8	6/10	8/10	10/12	4/7	5/7	6/7	5/8	7/8	5/9	7/9	8/9	7/10	9/10	6/11	7/11	8/11	9/11	10/11	7/12	11/12
1. *high*-low (hoog-laag)	42	34	34	47	44	63	23	31	32	30	40	36	39	46	45	59	44	45	52	55	63	56	68
2. *sharp*-round (scherp-rond)	23	35	25	34	42	48	23	23	27	29	31	37	37	54	33	59	50	42	49	47	57	44	63
3. *beautiful*-ugly (mooi-lelijk)	29	35	38	37	39	41	36	33	34	45	33	28	41	21	36	10	24	34	25	26	13	31	07
4. *active*-passive (actief-passief)	36	40	33	34	30	46	28	37	38	29	39	36	43	49	42	56	42	45	45	47	44	44	53
5. *consonant*-dissonant (consonant-dissonant)	46	53	55	53	50	53	50	57	47	57	37	39	51	23	48	20	30	34	34	38	20	39	18
6. *euphonious*-diseuphonious (welluidend-onwelluidend)	48	47	53	49	49	59	38	48	47	58	49	33	55	26	49	22	34	44	31	47	22	44	19
7. *wide*-narrow (wijd-nauw)	51	48	45	48	46	34	51	54	49	48	41	39	47	30	43	21	35	39	34	28	22	39	19
8. *sounds like one tone*-sounds like more tones (klinkt als een toon-klinkt als meer tonen)	52	32	33	39	37	31	33	23	22	34	17	41	31	15	35	20	32	36	38	32	17	39	22
9. *tense*-quiet (gespannen-rustig)	23	42	26	32	36	44	24	28	29	22	33	31	36	48	29	53	46	41	46	41	48	42	58
10. *rough*-smooth (ruw-glad)	25	26	29	27	36	43	29	31	44	26	41	34	37	57	37	58	42	40	45	49	61	36	61

interval against the first 7-point scale: "high-low". Thereupon the series was repeated in order to have the subject judge the intervals against the next scale, and so on, until all ten scales had been used. The sequence of the intervals in the series, and of the ten scales was varied to reduce order effects, with the exception that the scale "high-low" was always the first one.

RESULTS

Table 1 gives the judgments of the 23 intervals on the 10 scales (summated over the 10 subjects). The correlations between the scales were computed, and the correlation matrix was factor analysed (centroïd method). The unrotated factormatrix is given in table 2. Four factors have been extracted. The fourth factor explained only about 2.5 % of the total variance and will be neglected in the following.

TABLE 2.

Unrotated and rotated factor matrix (with λ-matrix).

	F_1	F_2	F_3	F_4	h^2			F'_1	F'_2	F'_3
1.	.810	.438	.115	—.314	.960	(high)	1.	.766	.026	.084
2.	.931	.300	—.140	.109	.988	(sharp)	2.	.672	—.283	.010
3.	—.882	.230	.206	.133	.891	(beautiful)	3.	—.172	.499	—.069
4.	.846	.151	.103	—.060	.753	(active)	4.	.525	—.086	.258
5.	—.928	.222	.237	.099	.976	(consonant)	5.	—.196	.537	—.036
6.	—.785	.385	.283	.131	.862	(euphonious)	6.	.018	.593	—.030
7.	—.955	—.117	.035	.061	.931	(wide)	7.	—.530	.252	—.096
8.	—.532	.313	—.290	—.300	.555	(one tone)	8.	.010	—.020	—.479
9.	.889	.255	—.059	.203	.900	(tense)	9.	.621	—.212	.009
10.	.967	—.076	.353	—.068	1.070	(rough)	10.	.403	.036	.524

λ	F_1	F_2	F_3
F'_1	.45	.89	.10
F'_2	—.27	.32	.91
F'_3	.18	—.38	.91

A simple structure rotation was performed in order to find the psychologically relevant dimensions. Simple structure asked for oblique factors. The correlations between scales and factors are also given in table 2; these correlations will be called the factor saturations of the scales.

Factor I

High saturations in this factor are found in scales 1 (high), 2 (sharp), 9 (tense), 7 (narrow) and 4 (active). This factor may provisionally be labeled: *pitch.*

Factor II

Scales 6 (euphonious), 5 (consonant), and 3 (beautiful) have high saturations in this factor, which is interpreted accordingly to represent: *evaluation.*

Factor III

High in 10 (rough), 8 (more tones), 4 (active): *fusion.*

These factors give some insight into the semantic connotation of consonance. The only substantiative saturation of this scale is with factor II, a clearly evaluative factor. So we can state: *For subjects who are not professional musicians, the judgment "consonant" is an evaluation of the interval.*

A point of interest is that consonance is connotatively quite different from fusion, since the consonance scale is only lowly saturated with factor III. The theoretical implications of this finding will be developed in the discussion.

The consonance scale has also a low saturation with factor I. As a matter of fact, this saturation in the pitch factor cannot adequately be explained. In the description of apparatus it was shown that the pitch could not be chosen freely. Calculation showed that there was in fact a correlation of .577 between average pitch of the interval and the complexity of the ratio [1]. If consonance has something to do with this ratio simplicity and nothing with pitch, still a correlation can be expected between the consonance judgments and the high-low judgments. Correlation between characteristics of stimuli always leds to correlation between

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[1] Complexity of ratio is quantitatively defined as follows: the ratio of the two frequencies of the tones of the interval is simplified as much as possible; so octave becomes 1 : 2, sixth 5 : 8, etc. The larger of the two numbers is the measure of complexity: octave = 2, fifth = 3, sext = 8, etc. Simplicity is the opposite of complexity.

the corresponding subjective scales, also in the case that these scales are connotatively independent of each other. So in our case, in spite of the correlation between the scales "consonant" and "high" (and with that of factors I and II—see λ-matrix, table 2), it is quite well possible that these scales (and the corresponding factors) are connotatively independent. However, it is impossible to be conclusive on this point.

It is interesting to see how the three semantic dimensions are related to some physical quantities. We can expect the first factor to show the relation with the mean pitch of the interval. This relation is depicted in figure 1. This figure speaks for itself.

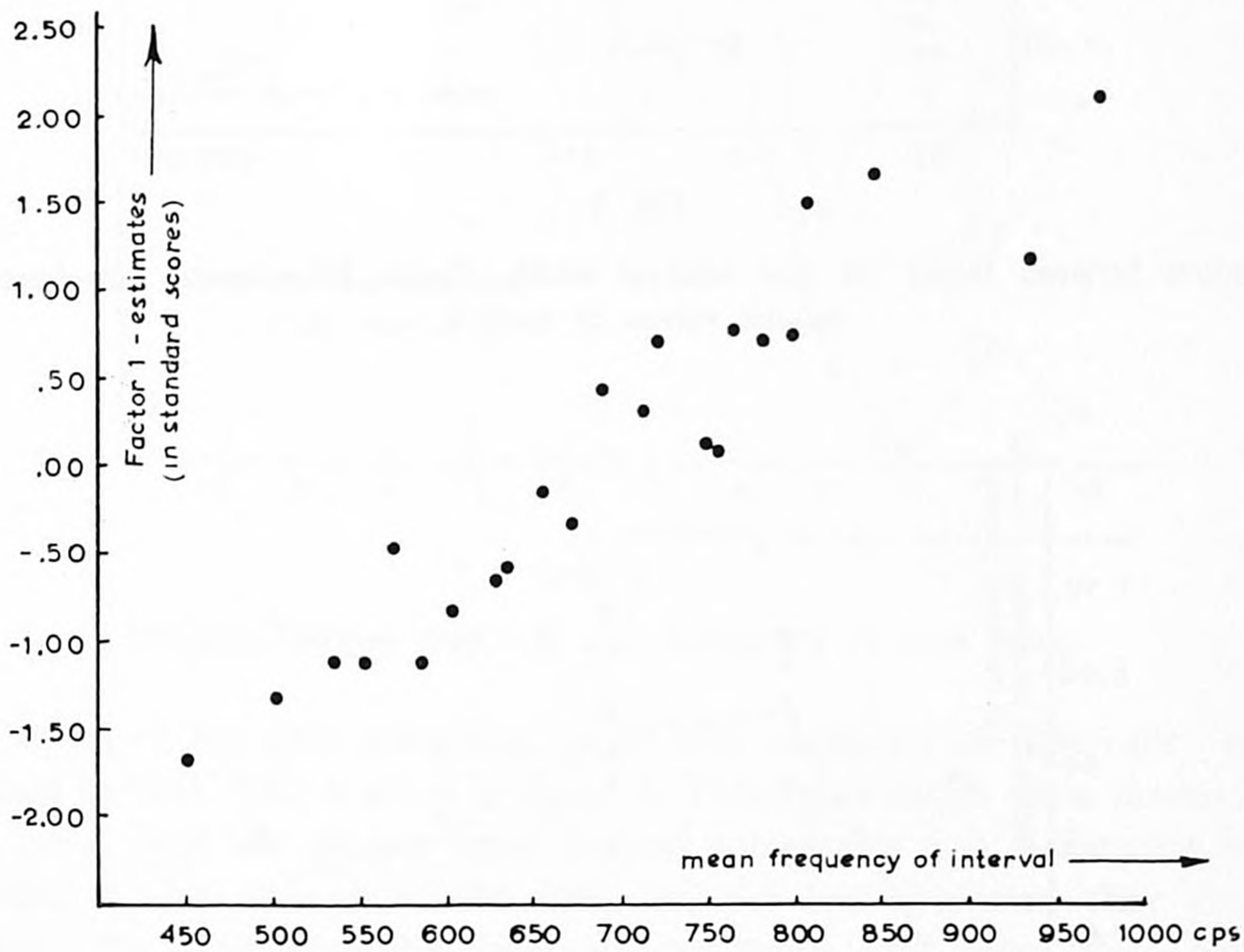

Fig. 1

Relation between factor I and mean frequency. Factor I-estimates are obtained by adding the values of scales 1 and 2.

Factor III (fusion) shows a clear relation with the distance between the tones (in cps.): the fusion increases, with increasing distance (figure 2).

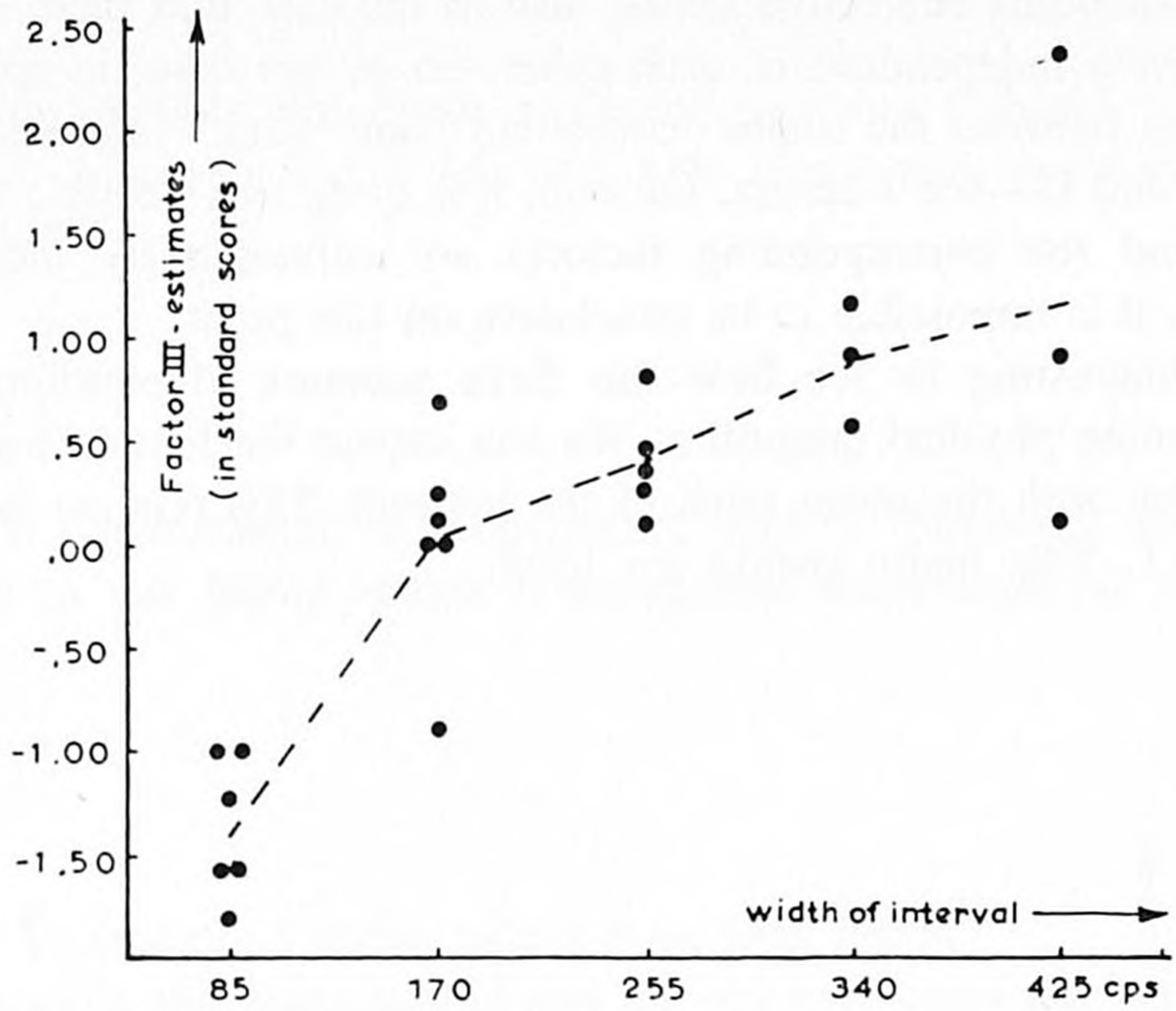

Fig. 2

Relation between factor III and interval width. Factor III-estimates are based on the values of scale 8.

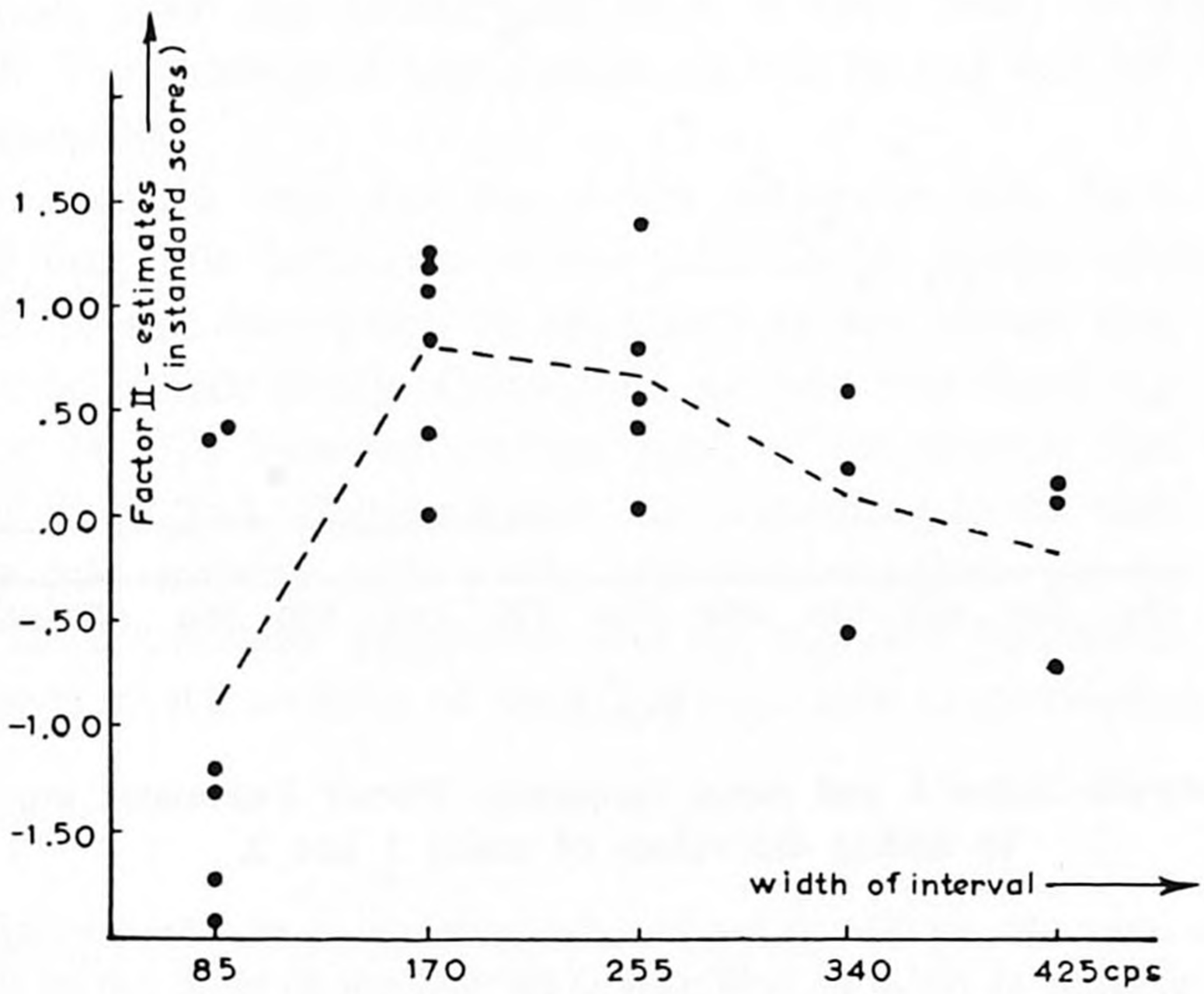

Fig. 3

Relation between factor II and interval width. Factor II-estimates are obtained by adding the values of scales 3 and 6.

Factor II (evaluation) does not show such clear-cut connections with physical variables. The relation with distance in cps. between the tones is given in figure 3.

Up till 170 cps., the trend in this figure is the same as for fusion (figure 2). In this range a steep rise in evaluation appears, along with a similar rise in fusion. But beyond 170 cps. consonance shows a slight decrease, whereas fusion continues to increase.

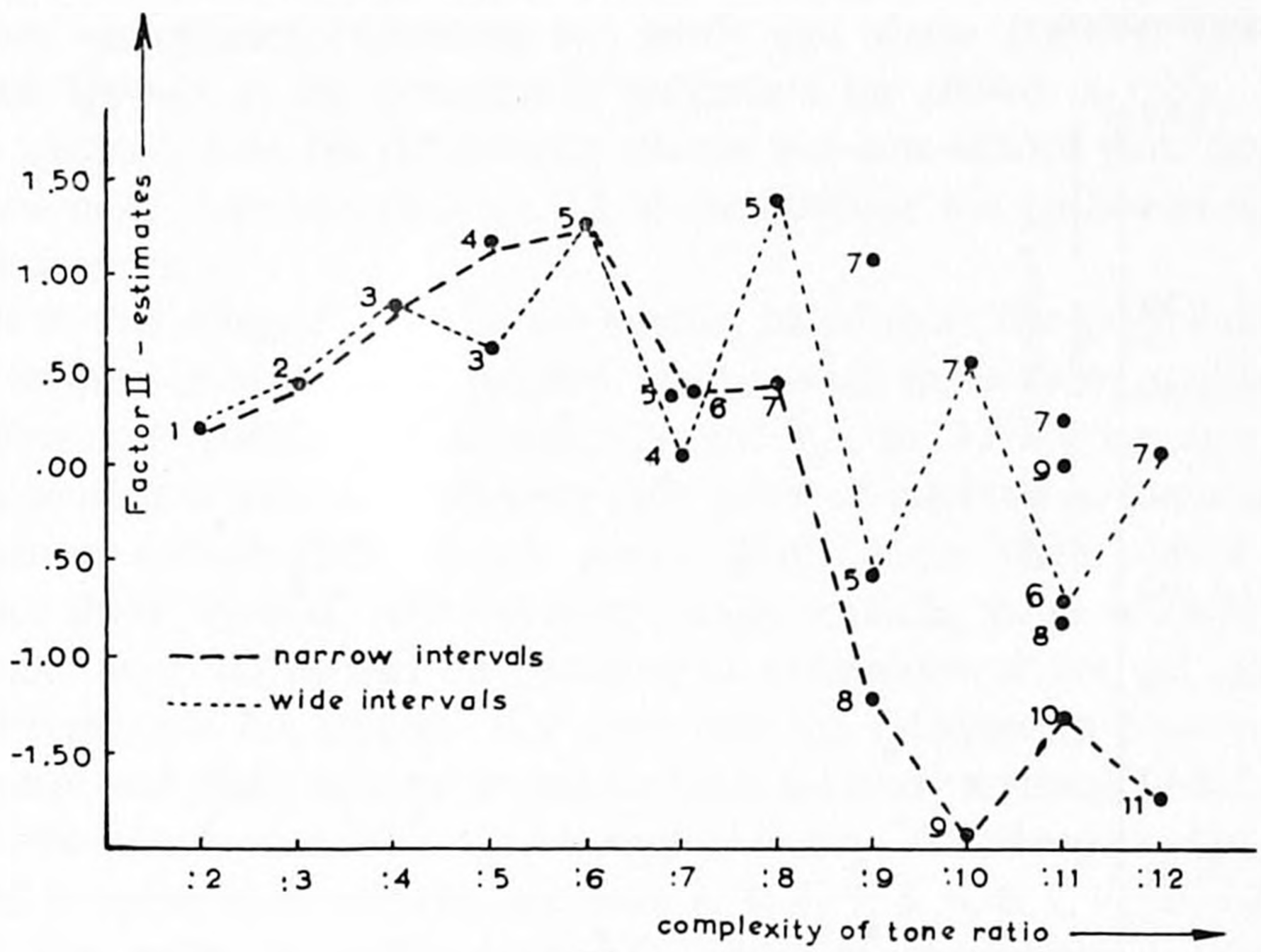

Fig. 4

Relation between factor II and complexity of tone ratio.

Evaluation has also something to do with simplicity of tone ratio (as defined before). This is given in figure 4. This figure shows some interesting facts. First the general trend beyond complexity 6 is a decrease in evaluation. The complexer the intervals, the less evaluated they are. Second, the most evaluated intervals are major and minor third and minor sixth, *not* octave, fifth and fourth. Third, the narrow intervals 6 : 7, 7 : 8, 8 : 9 etc.) are generally lower evaluated than the wide intervals (like 4 : 7, 5 : 8, 6 : 9, etc.). This is in accordance with the relation between evaluation and absolute distance as shown in figure 3.

Discussion

"Consonant-dissonant" is used by the subject as an evaluative contrast. It does not have substantiative saturations in the other two factors

("pitch" and "fusion"). So we can state that subjects do very well differentiate between consonance and fusion. According to Stumpf (6) the basic dimension in judging intervals would be the dimension of fusion, and consonance would be a derivative characteristic, in that an interval is consonant if it gives a subjective impression of fusion. In our study, indeed, fusion appears as a basic dimension in the perception of musical intervals, but we do not find a clear cut relation between this dimension and consonance.

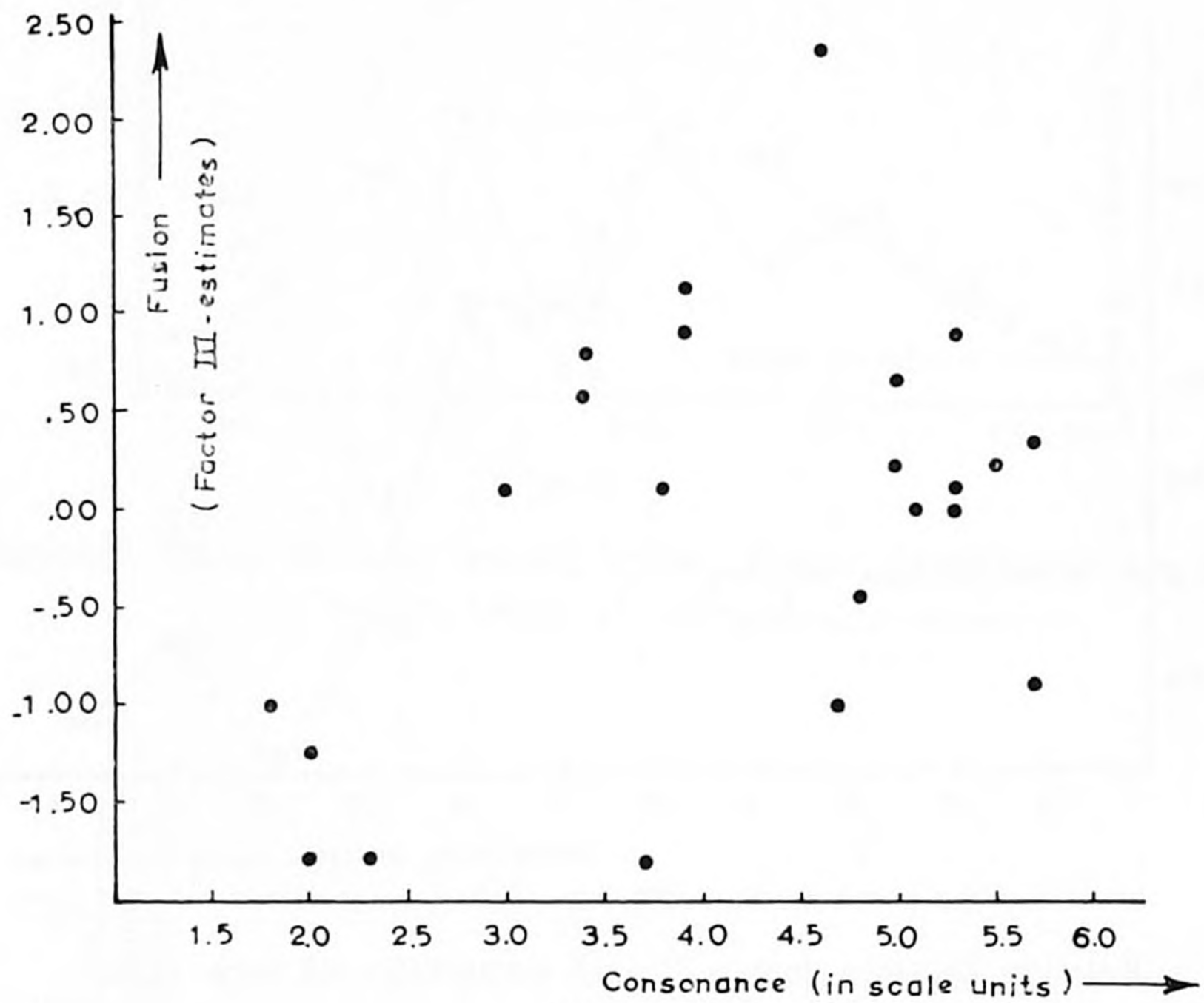

Fig. 5

Relation between consonance and fusion (factor III).

Figure 5 shows this relationship. From a comparison of figures 2 and 3 it is seen that, only in the region up to 170 cps. distance between the tones, fusion and evaluation show the same relation with absolute distance. There is only a connection between fusion and evaluation therefore for the narrow intervals. These intervals are low in evaluation (i.c. dissonant) and they are also low in the fusion factor. They are indeed the very narrow intervals 8 : 9, 9 : 10, 10 : 11 and 11 : 12.

Evaluation increases rapidly with a rise in interval width from 85 to 170 cps. (fig. 3). With wider intervals there is a slight decrease. So intervals are maximally evaluated when the distance between the tones is somewhere in the region of 170 cps. It might be that with this distance the

tones are not so far apart, that they are experienced as unrelated, nor so near that there is a disturbing interference of the tones; the optimal distance then makes the experience of the combination "interesting" or "exciting". Further research (4) indicated that there is a clear connection between consonance impression and the physiological phenomenon of "critical bandwidth" (1).

The relation between evaluation and simplicity of frequency ratio shows an optimal evaluation for thirds and sixths (fig. 4). The same trend appears in the consonance judgments (as shown in table 1), but less distinct: here the octave only shows less consonance than the other "consonant" intervals (it is nr. 12, if the intervals are ranked in order of consonance).

It is interesting to compare our results, based upon the judgments given by laymen in matters of musical theory, with those from studies with professional musicians. Malmberg (2, cited in 5, p. 131) for instance found that musicians gave the following rank order of intervals in terms of consonance: octave, firth, fourth, major third, major sixth, minor sixth, minor third, tritonus, minor seventh, major seventh, major second, minor second. So it seems that the meaning of consonance is not the same for musicians and for laymen. For musicians the relationship between consonance and complexity of frequence ratio is clearly a straight one, as it is also the case in treatises on musicological theory. Malmberg's order, translated in terms of complexity, becomes 2, 3, 4, 5, 5, 8, 6, 7, 9, 15, 10, 16 [2], and this order is rather constantly given in musicological litterature throughout the ages.

This use of consonance by musicians however, is not strictly related to their evaluation of intervals (as it appears with laymen); it seems that the evaluation did undergo considerable changes throughout the centuries. To illustrate this: the Pythagoreans held the intervals prime, octave, fifth and fourth in very high esteem, since they should be considered as an expression of harmony and simplicity. In the late middle ages (M.A.) the evaluation was strongly changed and major third became highly evaluated. Still later on the minor third, too, came into esteem. One possible reason for this is that these intervals differentiate between the two scales *major* and *minor* which at the beginning of the musical Renaissance (16th century in France) had been developed from the large number of "church scales" (Zarlino 1558).

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[2] This complexity order only holds, if the intervals are conceived of as "naturally tuned". In the pythagorean tuning f.i. the tritonus is a very complex interval (512 : 729).

A second reason for a change in evaluation is the unfolding of the polyphonic composition style in the early M.A. (9th century). Before this period tones were only given in a *succession*, but the polyphonic style implies the *simultaneous* use of different voices, separated by intervals. The result was that the most fusing intervals were not the optimal ones with respect to the aesthetic ideal of polyphonic music. This undoubtedly reduced the evaluation of the most consonant intervals—in the 14th century; the use of octave and fifth parallels was even forbidden (Joh. de Muris) [3]. Intervals which are less fusing, such as thirds and sixths accordingly did show a rise in evaluation. In the Ars Nova the major third was called *"dulcis"*.

Most theoreticians of the M.A., however, were not disturbed by this factual development of aesthetic appreciation, and maintained the old, philosophical, classification according to which prime, octave, fifth and fourth are consonants, and the other intervals dissonants. Thus, in this theoretical use, the concept of consonance has survived until our days; it even survived the developments of homophonic and twelve-tone styles. It is a clear and unambiguous conception, which has appeared unvulnerable against aesthetic considerations. The only concession to the change of taste is perhaps the introduction of the term "imperfect consonant" for the third and the sixth (Walter Odington, 13th century).

So it was probably in the M.A., with the origin of the polyphonic techniques, that musicological consonance and aesthetic evaluation differentiated in meaning. The layman's consonance conception however did not diminish in clarity either. It remained evaluative and according to our results this is still the case.

We may conclude:

1. In the judgment of musical intervals three basic dimensions are found: pitch, evaluation and fusion.
2. Layman's conception of consonance is evaluative. The musicological meaning is a different one; in musical theory the consonants are always prime, octave, fifth and fourth, irrespective of aesthetic considerations.
3. There is no straightforward relation between consonance and fusion.

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[3] However this is also connected with the introduction of the four-part compositions. In these compositions namely, the use of octave and fifth parallels necessarily leads to doubling of tones.

4. Octave, fifth and fourth are not the most evaluated intervals, but thirds and sixths.

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SUMMARY

As a preliminary to further research on musical consonance an exploratory investigation was made on the different modes of judgment of musical intervals. This was done by way of a semantic differential.

Subjects rated 23 intervals against 10 scales. In a factor analysis three factors appeared: pitch, evaluation and fusion. The relation between these factors and some physical characteristics has been investigated. The scale consonant-dissonant showed to be purely evaluative (in opposition to Stumpf's theory). This evaluative connotation is not in accordance with the musicological meaning of consonance. Suggestions to account for this difference have been given.

REFERENCES

1. Feldtkeller, R., and Zwicker, E., *Das Ohr als Nachrichtenempfänger*. Stuttgart 1956.
2. Malmberg, C. F., *The perception of consonance and dissonance*. I. a. St. Ps. VII, 1918, 93-133.
3. Osgood, Ch. E., Suci, G. J., and Tannenbaum, P. H., *The measurement of meaning*. Urbana 1956.
4. Plomp, R., and Levelt, W. J. M., *Musical consonance and critical bandwidth*. Proc. Fourth Intern. Congress on Accoustics, Copenhagen 1962.
5. Seashore, C. E., *Psychology of music*. London 1938.
6. Stumpf, C., *Tonpsychologie*. 1883-1890.
7. Torgerson, W. S., *Theory and methods of scaling*. New York 1958.