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Sundberg, J. and Verrillo, V.

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III. MUSICAL ACOUSTICS

A. ON THE ANATOMY OF THE RETARD. A study of timing in music.

J. Sundberg and V. Verrillo*

Abstract

The timing of the last tones constituting the final retard is studied in performances of motor music, i. e. music dominated by long sequences of short and equal note values frequently accompanied by similar series of twice as long note values. The results suggest that the retard length is related to the length of the final cadence and that the retards are divided into two phases, the first of which is variable while the second is more regular; its length and decrease in velocity depends on the length of the last conceptual unit (motive) of the piece and,as regards the decrease of velocity,also the preretard mean velocity, with which the piece is played. The same preretard mean velocity also determines the duration of the note preceding the final chord. These observations are expressed in a set of equations by means of which retards are computed for a set of compositions. The musical quality of such rule generated retards is assessed by a jury of experienced musicians and music listeners.

Introduction

The performance of a given musical composition must fulfill certain demands in order to sound acceptable to a musically trained listener. This is certainly not to claim that there is only one performance of the composition which is acceptable. Rather, it is to say that all members of the class "acceptable performance" obey certain rules. We can hypothesize that these rules possess a certain degree of generality within a given class of composition which may provide information on the system we used when we listen to and "understand" a piece of music. The purpose of the present investigation was to collect and describe data on the timing of the last sequence of notes in acceptable performances or, more specifically, the final retards. Certainly, there are many acceptable ways of performing a final retard. Indeed, in some performances there seems to be no retard at all. This investigation focuses on one type of final retard which is typically found in music which can be labelled "motor music", i. e. music presenting long series of short and equal note values frequently accompanied by similar series of twice as long note values, cf. Fig. III-A-1. Such patterns were very common in keyboard music of the baroque era. Thus, the kind of retard usually employed in the performance of this type of music was selected for analysis.

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* Violet Verrillo from Syracuse, New York, USA was a guest researcher from February - October 1977.

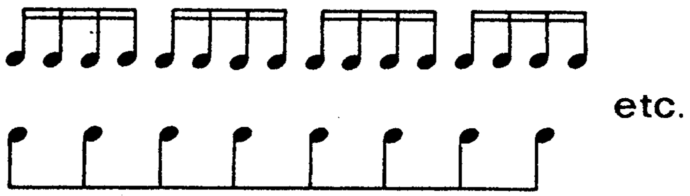

Fig. III-A-1. Metric organization typical for motor music.

The general outline of the investigation was as follows. An analysis of 24 final retards was performed and a mathematical model was devised to describe the observations. Thirteen retards were computed using this model and then presented to a jury of 20 musically experienced listeners.

Part I: Model Development

Material

In order to find a class of musically acceptable performances we chose phonograph recordings, mainly consisting of keyboard music played on the harpsichord, cf. Table III-A-I (only the Hayden sonata and the WKF5 performed by B were played on piano and by an ensemble, respectively). Most of the 24 pieces selected were written by J. S. Bach, who frequently worked with just the type of compositional technique mentioned above. In gathering material from the recordings, special care was taken to obtain typical examples, eliminating those which had exceptionally short, long or in other respects devient retards. Moreover, to facilitate measurement pieces were preferred which maintained a progression of short note values until the final chord.

Analysis

The material was analyzed on a Voice-Print using narrow band filtering and double tape speed. In the obtained recordings, 1.0 mm corresponded to 15.2 msec allowing an accuracy of approximately ± 4 msec. Measurement of the note durations was extended over the last 15-30 sec of the piece to provide information on the preretard mean velocity with which the piece was played; the velocity was defined as the inverse of the duration. Tone onset was defined as the first trace of sound discontinuity and tone duration as the time between two adjacent tone onsets, cf. Bengtsson et al (1969). The shortest note values were identified in the records and their durations were measured. Henceforth, we will refer to this note values as the shortest unit. (In two cases where the shortest unit existed in one single bar only, the next longer note value was defined as the shortest unit.)

The durations of the shortest units were inverted to obtain a measure of the instant velocity and plotted according to their distance from the final chord (cf. Fig. III-A-2). Plots showing the instant velocity of each shortest unit will be referred to as retard curves. Retard length in shortest units was determined from these retard curves being the sequence of shortest units all of which were slower than the preretard

TABLE III-A-I.

Composer	Piece	Per-former	Abbrev.	FCL (Beats)	RL (Beats)	LCU (SU)	PhIIL (SU)	$\bar{V}$ (SU/sec)	PhIISl (ΔV/SU)	LVM (SU/sec)	
J. S. Bach	Wohltemp. clavIPrel. 1	A	WKIP	24(16)	11	6	6	4.46	0.32	1.03	
"	" " IIPrel. 1	A	WKP1	8	6	7(3)	7	3.09	0.22	2.74	1)
"	" " IIPrel. 2	A	WKP2	8	7.5	3	3	5.37	0.33	2.43	
"	" " IIFug. 3	A	WKF3	2.5	2.7	3	5	3.19	0.35	1.19	
"	" " IIFug. 5	A	WKF5	12	10	3	3	1.78	0.26	.88	
"	" " IIFug. 5	B	WKF5	12	7	3	3	2.07	0.31	.72	
"	" " IIPrel. 11	A	WKP11	8	8	3	3	4.10	0.59	1.37	
"	" " IIFug. 11	A	WKF11	2.3	2.7	3	3	4.73	0.87	2.44	
"	" " IIPrel. 19	A	WKP19	3.3	4.7	3	3	3.44	0.43	1.57	
"	Eng. Suite 1-Prel.	C	E1P	6	4.6	4	3	3.98	0.54	1.59	
"	" " 1 Allem.	C	E1A	6	3	3	6	3.45	0.45	1.40	
"	" " 1 Bourée	C	E1B	7	4	7	6	5.94	0.42	1.78	2)
"	" " 2-Prel.	C	E2P	6	6	3	3	6.48	0.43	1.73	
"	" " 2 Allem.	C	E2A	6	4	5	6	3.81	0.38	1.60	
"	French Suite 2-Cour	C	F2C	7	4	3	5	6.25	0.62	2.99	
"	" " 4-Allem.	C	F4A	7	5.5	3	3	4.12	0.65	1.51	
"	" " 4-Cour	C	F4C	4.3	5	3	4	5.31	0.69	2.44	
"	" " 6-Allem.	C	F6A	7	9	3	3	4.72	0.54	1.78	
"	" " 6-Cour	C	F6C	8	6	3	3	6.41	0.93	2.48	
"	Italian Conc., Mvt 1	D	IC1	20(4)	16	4	-	6.28	-	0.91	2)
"	" " " 3	D	IC3	12(4)	13	6	7	6.70	0.70	1.01	
J. Hayden	Sonata # 41	E	H41	8	5	9	-	7.08	-	1.32	2)
D. Scarlatti	Sonata E 3/4	F	S 4	3	2	8	-	6.48	-	0.58	2)
"	Sonata E 6/8	F	S66	3	2	3	-	7.46	-	1.37	1)

FCL = final cadence length; RL = retard length; PhIIL = Phase II length; $\bar{V}$ = preretard mean velocity; PhIISl = Phase II slope; LVM = last velocity measure; SU = shortest units.

1) grace note   2) extrapolated

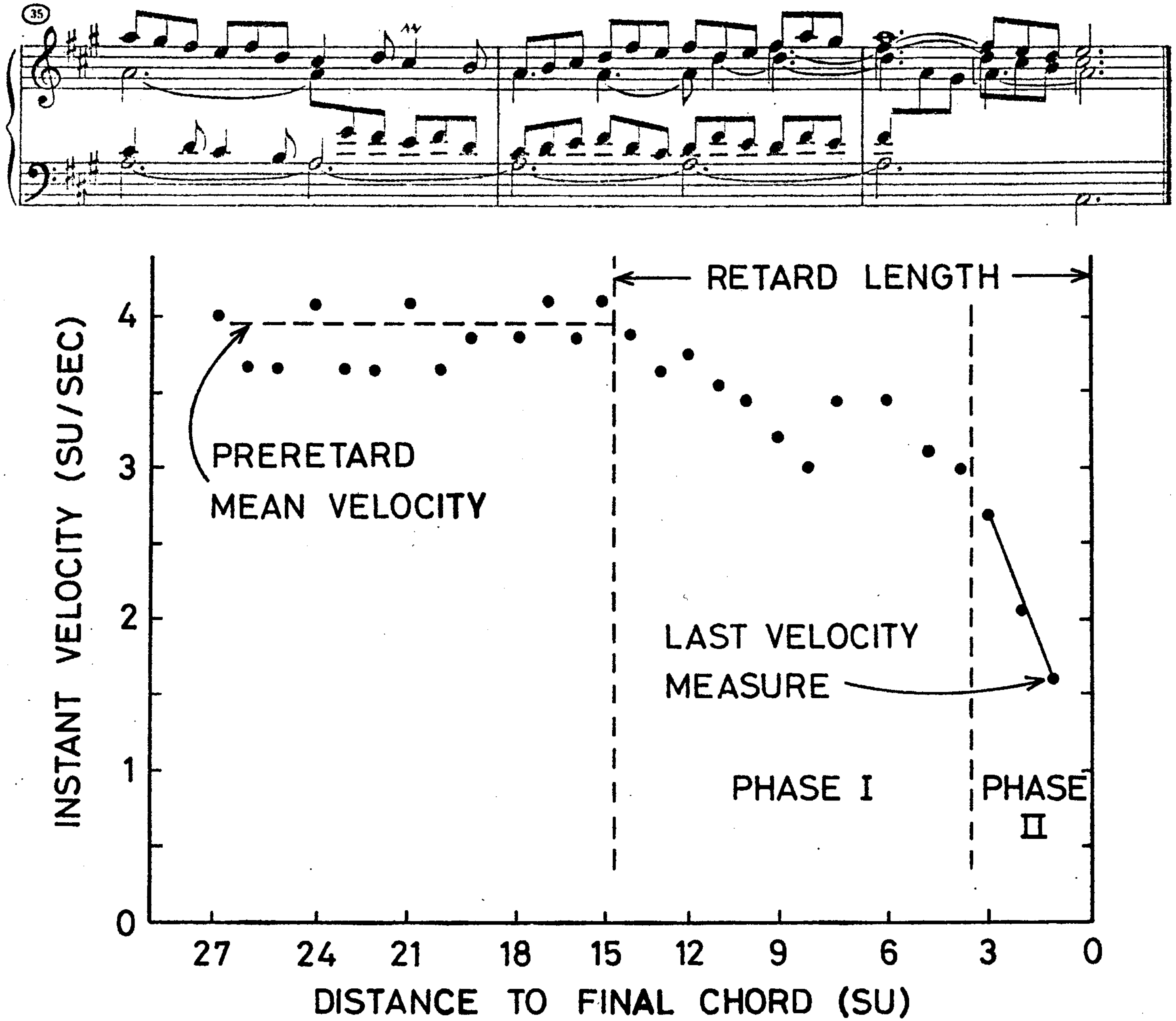

Fig. III-A-2. Example of retard curve (lower graph) describing the timing of the final portion of a piece, the notation of which is shown above.

mean velocity. Occasional single notes with velocities exceeding the preretard mean were disregarded. Such notes occurred mostly as grace notes, and in combination with trills. The endpoint of the retard was the onset of the final chord.

Results

In order to obtain an idea of how similar the 24 retards were, the retard curves were normalized with respect to retard time and preretard mean velocity. In each retard curve the velocity was linearly interpolated at each tenth of the retard time and the averages and standard deviations at each tenth of the retard curves were computed. At the beginning of the retard the standard deviations amount to ca 6 % and grow to about 11 % towards the end, as can be seen in Fig. III-A-3. The question now is what causes these considerable standard deviations.

A closer examination of the individual retard curves revealed that in all cases except four, the retard curve can be naturally divided into two parts. The first part is characterized by a shallow slope while the second shows a considerably steeper slope. Moreover, in contrast to the first part which shows a great variability between the pieces, the velocity decreases linearly in the second part in almost every retard curve. Thus, in most of the examples there was no difficulty presenting a straight line as a good approximation of the decrease in velocity in the second part of the retards. In some cases there was some ambiguity because the points fell along a slightly curved contour. On the other hand, in most of these cases there were only three data points in the second part, so that small errors in measurement or in performance may very well account for this curvedness. These findings made us hypothesize that retards are divided into two phases, the second of which can be described as a linear decrease of velocity. Consequently, phase II was approximated as a straight line wherever possible which was in all retard curves except four. Phase II length was defined as that part of the curve where the data points fall close to this straight line.

The retard length was found to correlate with the length of the final cadence formula, i.e. the last presentation of the dominant-tonic or subdominant-dominant-tonic chord sequence. Fig. III-A-4 shows this correlation. If that interpretation of final cadence length is chosen which

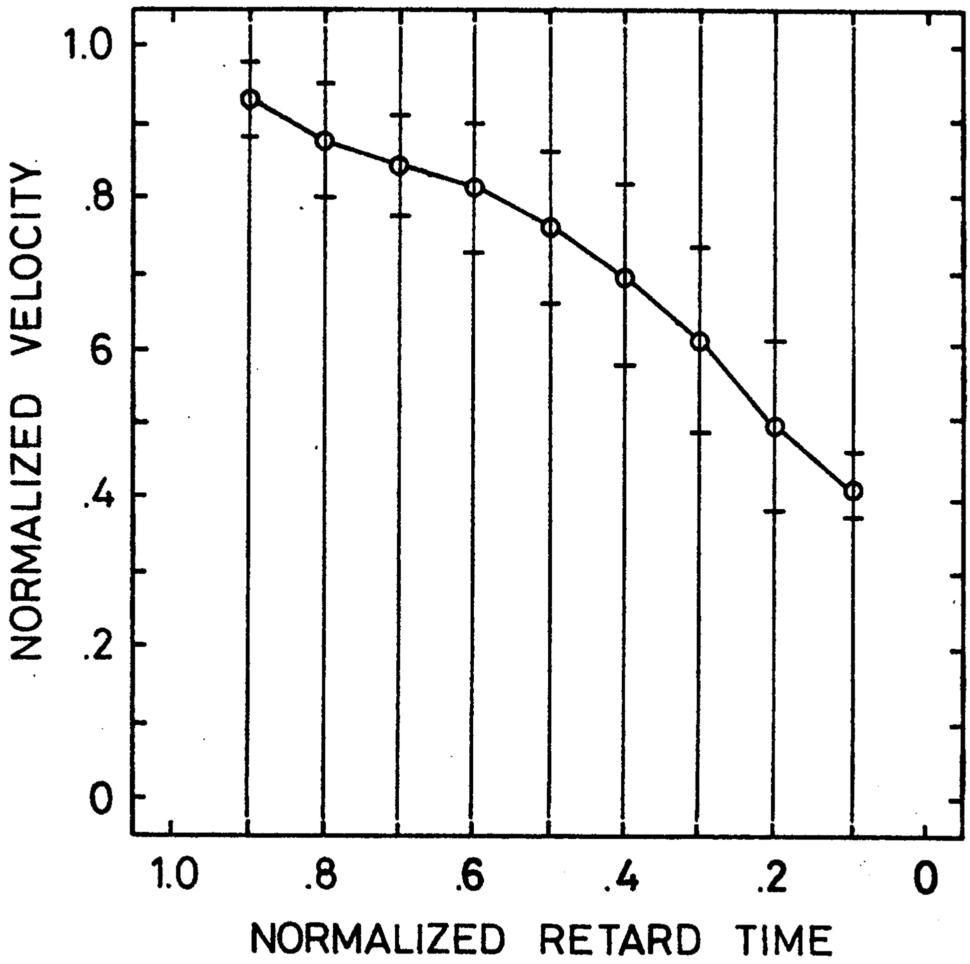

Fig. III-A-3. Averages of the normalized velocity in the 24 retards studied. The abscissa represents the normalized time which the retard takes. The bars show ± 1 standard deviation.

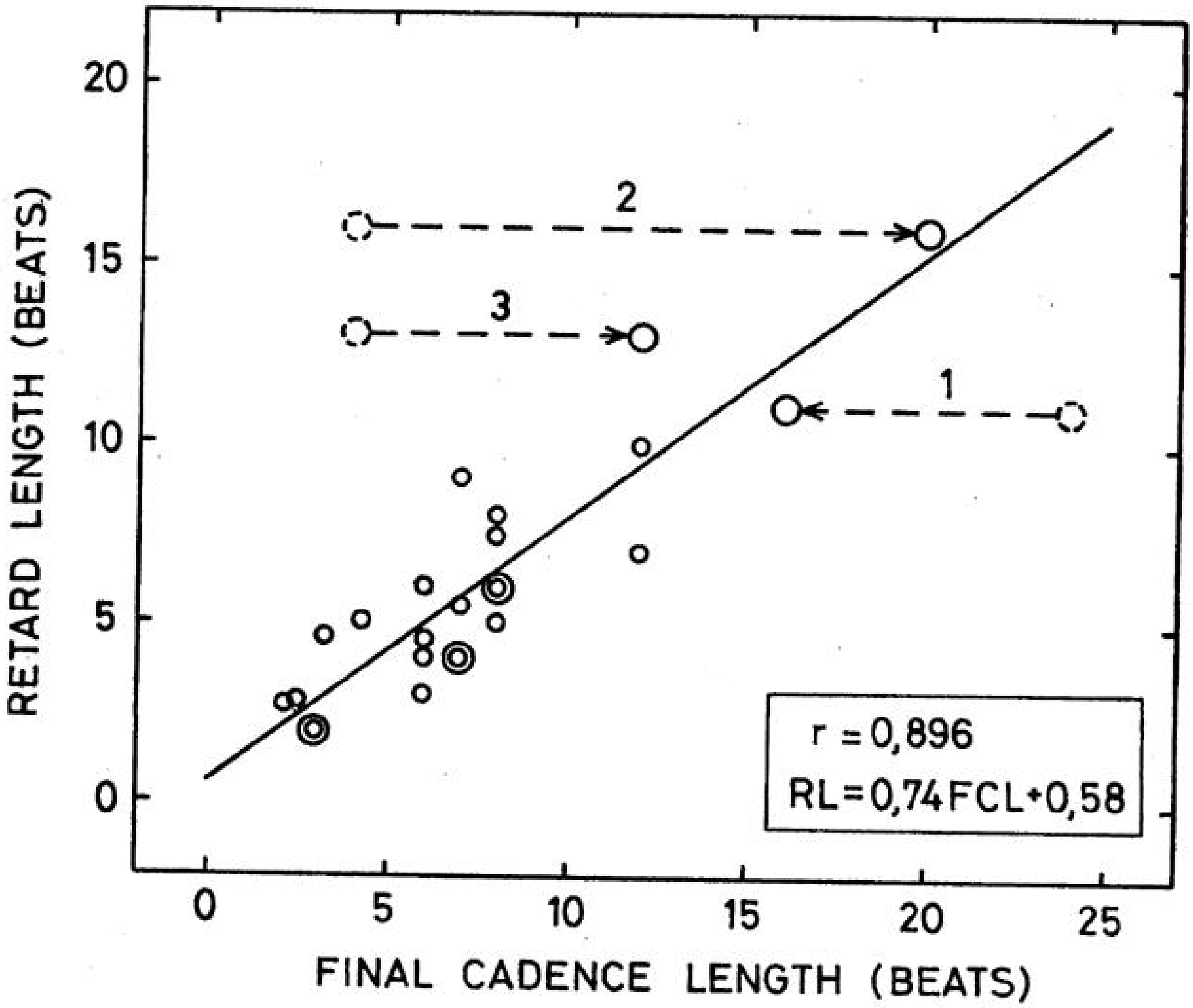

Fig. III-A-4. Relationship between the length of the final cadence (FCL) and of the retard (RL) in the 24 pieces studied. The line shows the approximation used in the model.

produces values conforming with the majority of data points, the plot yields a correlation coefficient of r = .896, and the retard length RL can be approximated as

$$RL = .74\ FCL + .58\ \text{(beats)} \qquad (1)$$

where FCL is final cadence length.

The Phase II length shows a correlation with another structural constituent in the music, namely the last motive, if defined as the last and shortest sequence of notes that constitute a melodic gestalt. We named it the last conceptual unit. As can be seen in Fig. III-A-5 the last conceptual unit length is in several cases almost identical with the Phase II length, the correlation coefficient being r = .749. We found it more practical to assume that Phase II length equals last conceptual unit length than to use an equation based on the least-square method and involving fractions of shortest units to approximate this correlation. Hence, Phase II length

$$PhIIL = LCU \qquad (2)$$

where LCU is the length of the last conceptual unit. The rate of decrease in velocity in Phase II, i.e. the Phase II slope, was found to vary with the preretard average velocity, but also Phase II length comes into play. Fig. III-A-6 shows the correlation between Phase II slope and preretard mean velocity. It can be seen in the figure that pieces with longer Phase II show less steep slopes than pieces where Phase II comprises three shortest units only. It seems natural that a less steeply sloping alternative is chosen when there are many notes available for making the final part of the retard. As to the scatter in the figure it should be born in mind that the length of the last conceptual unit can be interpreted differently by different observers. Thus, the performer may have made an interpretation other than the one we made and played accordingly. Thus, it is difficult to obtain objective data on this point and therefore we decided to approximate the data in the following way: the change of velocity per shortest unit

$$\Delta V/SU = .09\ \overline{V} + .124 \quad \text{for LCU shorter than 5SU} \qquad (3a)$$

$$\Delta V/SU = .062\ \overline{V} + .029 \quad \text{for LCU longer than 4SU} \qquad (3b)$$

where LCU is the last conceptual unit length, $\overline{V}$ is the preretard mean velocity, and SU is shortest units.

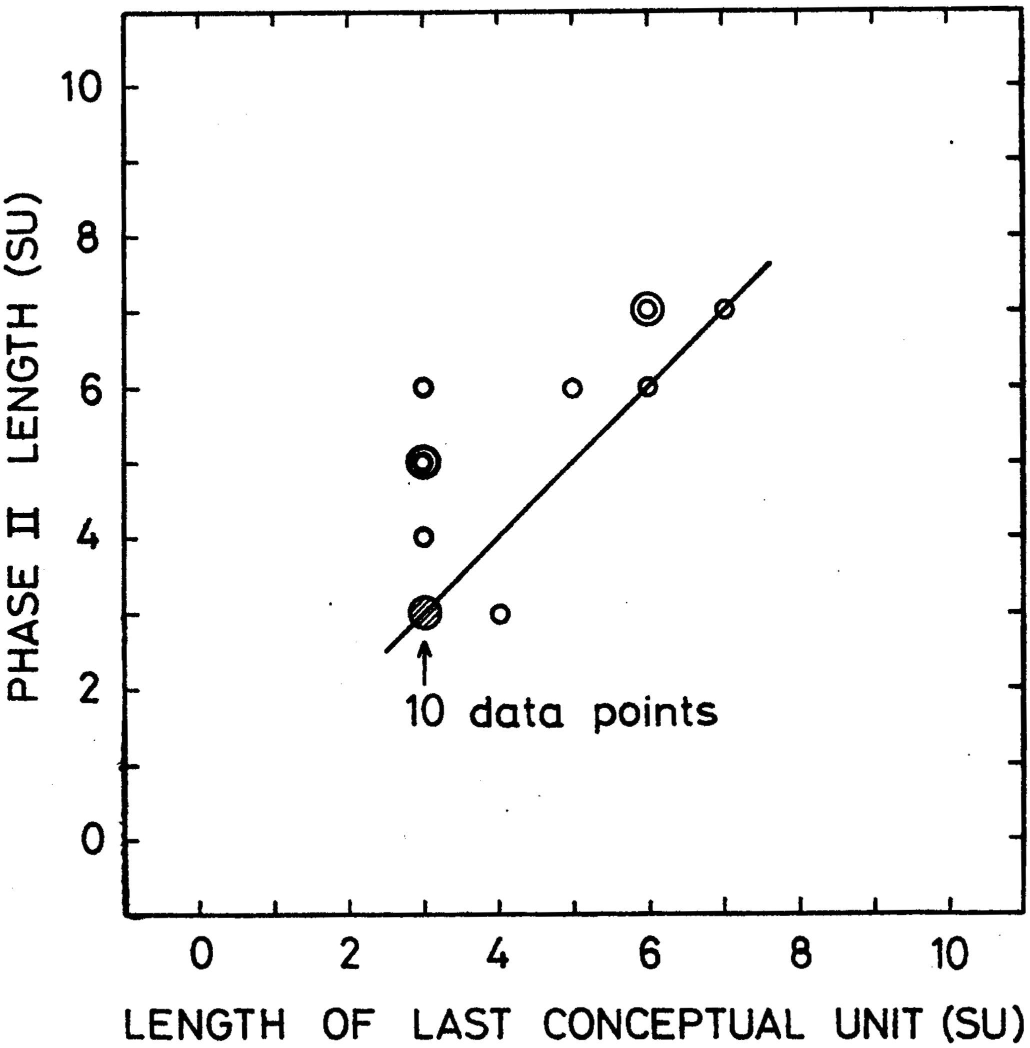

Fig. III-A-5. Relationship between the length of the last conceptual unit and of the Phase II length in the 20 pieces where the retard showed a clear separation between Phase I and Phase II. SU = shortest units. The line shows the approximation used in the model.

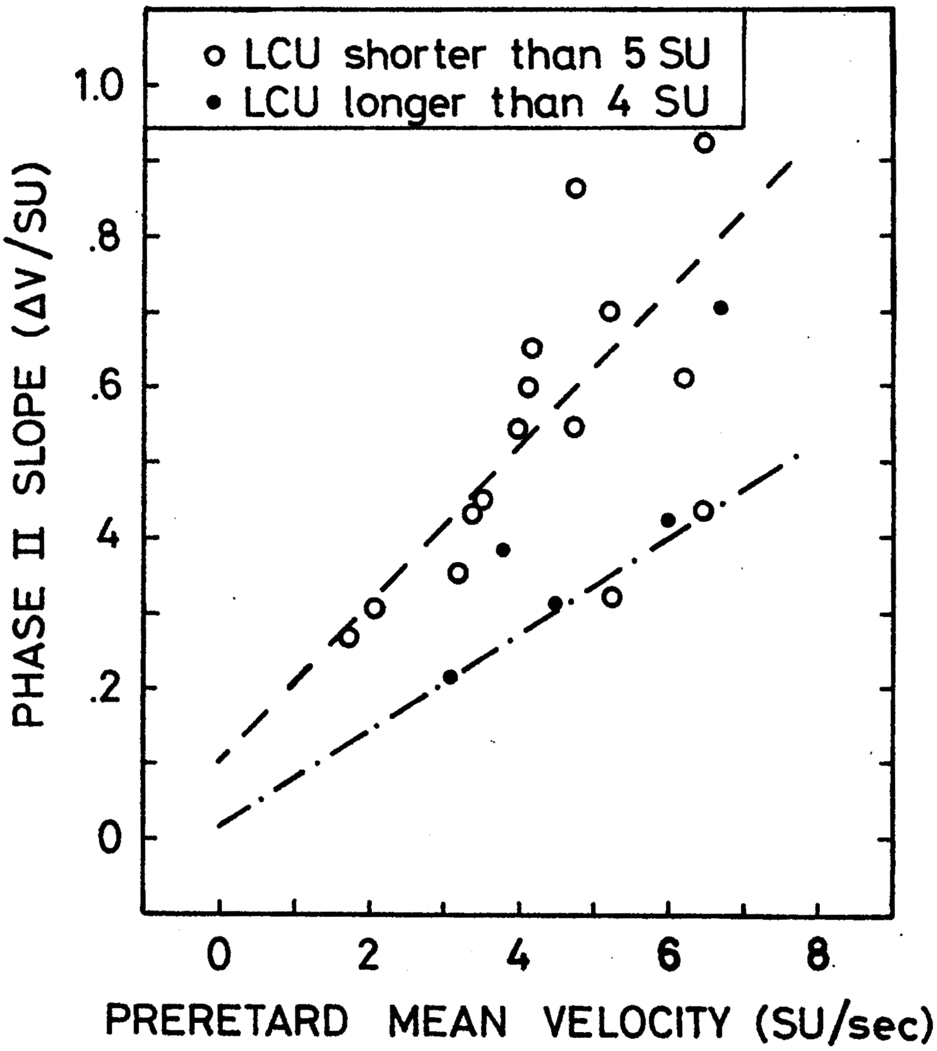

Fig. III-A-6. Relationship between preretard mean velocity and decrease of velocity in Phase II in the 20 pieces where the retard showed a clear separation between Phase I and Phase II. LCU = last conceptual unit. The lines show the approximations used in the model for LCU shorter (dashed line) and larger (chain-dashed line) than 5 and 4 shortest units.

The last velocity measure was found to correlate with the preretard mean velocity, as we might expect. The correlation is illustrated in Fig. III-A-7. With five exceptions the data points conform pretty closely to a straight line. Among these five exceptions there are one grace note, one suspension and one broken chord. Disregarding these examples the majority of the data points can be approximated by the equation

$$LVM = .56\,\overline{V} - .55 \quad (SU/sec) \qquad (4)$$

This equation simply states that the LVM (last velocity measure) is chosen with regard to the preretard mean velocity $\overline{V}$.

As for Phase I, the variability was great as mentioned, and no conclusive way was found to account for it. It was decided, then, to make a very crude and simple approximation of this segment in the following way. To mark off the beginning of the retard, the first shortest unit in the retard was made 95 % of the preretard mean velocity. The remaining shortest units of Phase I were given velocities that decreased linearly in the retard curve until the beginning of Phase II.

This terminates our observations on the 24 retards examined. The result can be summarized in the following way. The retard curves in the type of music considered here are divided into two phases, the first of which seems to be rather free while the second exhibits a linear decrease of velocity. The retard length depends on the length of the final cadence, cf. Eq. (1). The length of Phase II equals the length of the last conceptual unit, cf. Eq. (2). The slope of the retard curve in Phase II depends on two factors: the preretard mean velocity and the Phase II length, cf. Eq. (3a and 3b). The end point of Phase II, i.e. the last velocity measure, is related to the preretard mean velocity, cf. Eq. (4). It seems that these four equations explain the great variability between different retards when plotted as in Fig. III-A-3.

At this point we certainly cannot presume that the above description of the final retard in a motor music piece is tenable: the scatter of the data points in each plot prevents such a conclusion. In order to find out how much our descriptive mathematical model tells about musical reality we have to test it by predicting retards and presenting them to judges.

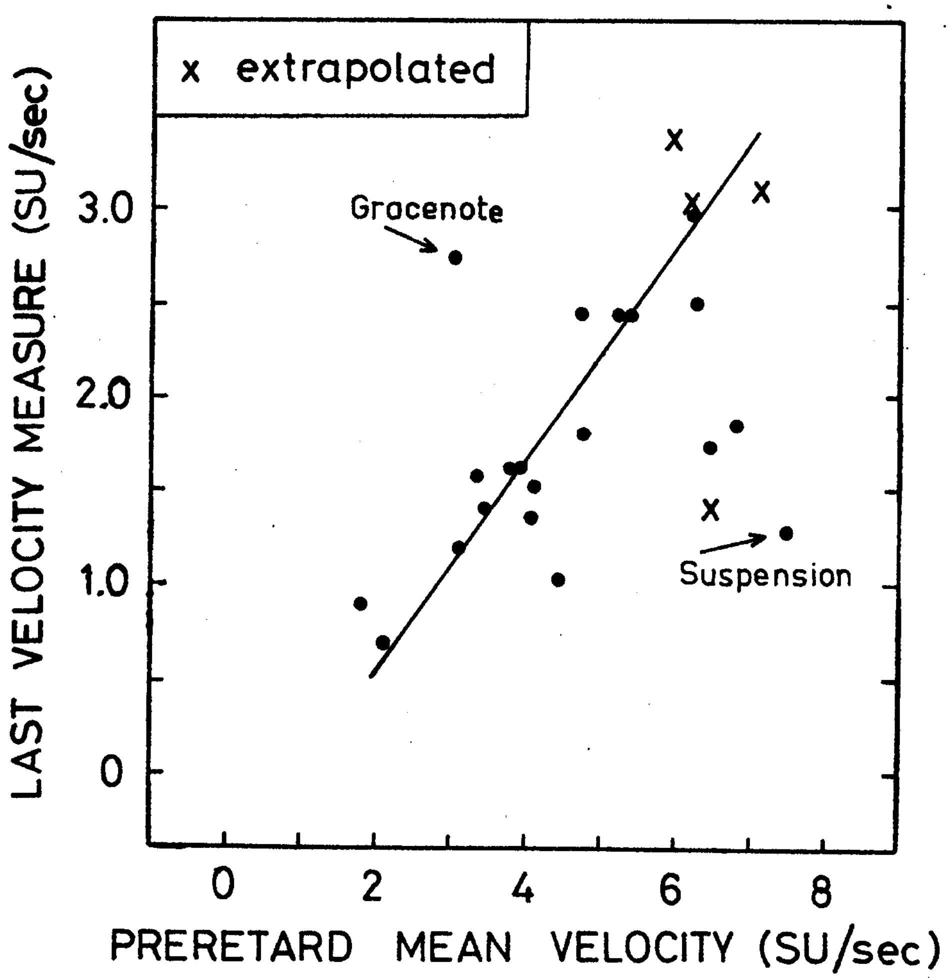

Fig. III-A-7. Relationship between preretard mean velocity and last velocity measure. In cases where the last velocity measure pertained to a note value longer than the shortest unit, the corresponding velocity was expressed in shortest units by extra-polation in the retard curve. The line shows the approximation used in the model.

Part II. Assessment of Model

Synthesis

In order to obtain fully controlled performances of retards computed by the model it is necessary to use synthesis. The best solution would have been to use the sound splicing computer program developed by Carlson and Granström. This program allows insertion and deletion of well defined parts of the time signal in a tape recorded signal. However, this solution was found impracticable because of the difficulties in producing edited versions of the examples that were free from click sounds arising from discontinuities in the spliced waveform. Therefore we chose to make one-part-versions of the examples to be synthesized and to use the MUSSE synthesizer for the sound generation (Larsson 1977). A control program was deviced by R. Carlson and B. Granström (1976) in which the pitches and their durations were specified. The sound generation was adjusted to produce a tone quality similar to that of a harpsichord.

Material

Our model was based on a series of correlations found between factors in the music and in the performance and factors in the retard. None of these correlations was perfect. Hence, retards predicted by our model will deviate more or less from the retards actually performed. An important question then is, do these deviations create retards that sound musically unacceptable?

In order to severely test the model we chose examples for synthesis of three types. One set was drawn from those predictions which deviated the most from the original performance on one of each of the four essential parameters of the model. There were two examples for each parameter. In one instance the example was devient in two parameters, the length of Phase II and its slope. In an additional example we substituted the slope of the original performance and retained Phase II length in its devient form. In another case the last conceptual unit of the composition was ambiguous; we generated two versions, one with three shortest units and one with seven for the Phase II length. This gave us nine examples in the most-devient class.

Another way to test the model was to synthesize a number of retards which were not predicted from the model and which did not have the two-phase system. We used five selections from the most-devient group, described earlier, and computed a linear decrease in velocity over the whole retard curve making it a straight line. These are referred to as "straight-line retards".

Finally there was a third set of retards which were not strongly devient from the actual performance in any parameter.

It would have been desirable to have still another category of retard, synthesized with the actual durations of the performance. The one-part reduction of the compositions, however, did not allow for good equivalence and the original durations produced unstable examples, which were unsuitable for comparison with the predicted version.

In this way we made a test tape consisting of 18 retard examples. Each example contained a complete final retard and a pre-retard segment of from 11 to 47 shortest units in the average velocity of the performance prior to the retard. The range in time for the examples was 4 1/2 sec to 13 sec and there was a pause between examples of 3 sec. The total time of the tape was about 10 min. Each selection was repeated, although not in sequence, so that each example was heard twice in the course of the tape. The durations of the notes in each example were checked by means of an oscillograph recording and were found to be in an agreement with the predicted values that were better than 15 msec.

Procedure

The test was run in a quiet room with the judges seated at a table 2 m from the tape recorder. The stimulus was presented to the judges over loudspeakers. The judges were instructed that they would be listening to a series of musical excerpts ending with retards. Their task was to assess these retards from a musical point of view on a five-point scale in the pause following each example, using five for the excellent retards and one for those which they considered unacceptable as musically feasible solutions. It was emphasized that they would listen to and judge only the retards, disregarding the quality of the synthesis, the melodic content, etc. Before the proper test began, a portion of the tape was played to familiarize the subject with the material. Two groups of judges were formed, one comprising professional musicians only and the other, non-professional musicians and experienced music listeners.

Results

As all examples were presented twice in the test each judge could be tested for consistency. As a measure of the individual judge's consistency, the difference between the two ratings of the same examples was computed for each judge and the absolute values of these differences for all 18 examples was averaged. There was no difference in average between the best members of the two groups of judges. Consequently, data from the two groups were combined and the subjects showing highest consistency were taken as one group. Henceforth the mean ratings made by this group of best subjects, regardless of their musical background, will be considered while ratings made by the less consistent subjects will be disregarded.

Table III-A-II lists all examples in rank order with regard to the average rating they received by the group of more consistent judges. The table also gives a set of values characterizing the retards. It can be seen in the table that the rating is inversely correlated with the standard deviation. This would mean that the judges' assessments agreed better in the cases of the low rated examples than high rated examples.

The first question to be asked concerns how well the model manages to account for the dependences of retards on the determining factors used for the model, i.e. final cadence length, last conceptual unit length, and preretard mean velocity. A correlation analysis was made between the ratings and each of the three factors. The resulting correlation coefficients are given in the same table. It can be seen that none of these factors shows a significant correlation with the ratings. This appears to support the hypothesis that the model was reasonably successful in describing how all these factors determine the retard. As we shall see below, however, this may not be fully true.

As can be seen in the table there is a significant correlation between rating and preretard length. One example, F2C, had the shortest preretard length of all examples. Moreover, the excerpt did not offer a reasonably complete musical statement as in the other examples. In other respects F2C was rather similar to example F6C which was ranked very high. These facts convinced us that the low rating of F2C was caused by other properties of the example than its retard. Correlations were recomputed, therefore, omitting example F2C. The new correlations between the ratings and the factors remained essentially the same with two

TABLE III-A-II

Example	Retard type	RATING Mean	SD	FCL (SU)	LCU (SU)	$\bar{V}$ (SU/sec)	Preretard length (SU)
WKP2	Pred	3.9	1.05	16	3	5.37	46
F6C	Pred[3]	3.7	1.09	20	3	6.41	30
F6A	Pred[1]	3.7	.97	14	3	4.72	23
E2P	SL	3.2	1.09	12	3	6.48	25
E1B	Pred	3.2	1.36	14	7	5.92	47
E1A	Pred[1]	3.0	1.03	12	3	3.45	22
F4A	Pred	3.0	.95	14	3	4.12	31
F6A	SL	3.0	.90	14	3	4.72	23
E2A	AP[2]	2.9	.93	12	5	3.81	32
E2P	Pred[4]	2.8	1.24	12	3	6.48	25
WTP11	Pred	2.5	1.07	16	3	4.10	37
E2A	Pred[2,3]	2.4	.88	12	5	3.81	32
E1A	SL	2.3	.92	12	3	3.45	22
F2C	Pred[2]	2.1	.97	14	3	6.25	11
F2C	SL	1.7	.75	14	3	6.25	11
WKP1	Pred[4]	1.7	.99	16	3	3.09	18
WKP1	Pred[4]	1.5	.69	16	7	3.09	18
WKP1	SL	1.4	.88	16	3	3.09	18
With F2C r =			.569*	.118	-.145	.441	.640**
Without F2C r =				-.002	-.229	.713**	.569*

Abbreviations as in Table III-A-I.

1 very devient in retard length

2 - " - phase II length

3 - " - phase II slope

4 - " - last velocity measure

* $p < .05$

** $p < .01$

exceptions. The correlations with preretard length dropped in significance while the correlation with preretard mean velocity became significant, thus suggesting that a high preretard velocity contributed to high rating. One interpretation of this would be that the model failed to mirror how retards depend on the velocity factor. Another interpretation is that the effect is due to the characteristics of the synthesis alone. The synthetic tones had a comparatively fast decay. In a slow tempo and particularly in retards this would create so long intervals between the fast decaying tones, that the result is considered unacceptable as a musically feasible solution. Indeed, some subjects made comments to that effect after having made the test. Thus, it does not seem evident that the model failed to describe how retards depend on the mean preretard velocity.

The next question is how well the model succeeded in predicting musically acceptable retards. This can be found out by two comparisons. One set of examples was presented with straight line retards as well as with model generated retards. If these two groups of examples are compared the result will demonstrate if the model-predicted retards were considered better than the straight-line retards. A second comparison would provide additional information on the same question. One set of retards was very devient from the actually performed retards, and another set of examples was less devient. If these two sets of examples are compared we may get an idea of how the model retards compared with the actually performed retards. In Table III-A-III the comparisons mentioned are made. The model-predicted retards were rated higher than the straight line retards in all cases except one (E2P). Still, the model-predicted retards received ratings that are significantly higher than for the straight line retards. This supports the conclusion that, provided that retard length and last velocity measure are equal, the division of the retard in two phases is important to the musical quality of a retard.

TABLE III-A-III

	Mean Rating	SD	N	Difference in rating	p
Model generated	2.67	1.24	98	0.36	< 0.05
Straight lines	2.31	1.13	99		
Very devient	3.27	1.20	100	0.80	< 0.01
Less devient	2.47	1.24	120		

According to the data given in Table III-A-III there is a significantly higher preference for the retards which deviate less from those performed. This suggests that our model has failed to take into account some relevant factors. If we examine Table III-A-II once more it can be seen that for instance the two examples showing a great discrepancy between model prediction and performance regarding retard length (F6A and E1A) nevertheless were ranked comparatively high. This may suggest that the model predicted fairly acceptable retard lengths. Examples deviating considerably in last velocity measure and in Phase II length, on the other hand, are found low in the ranking list. Note also that a great discrepancy in Phase II slope and length (E2A) gave a lower rating than when the same example was presented with a great discrepancy in Phase II length only. Tentatively we may hypothesize that the discrepancies as regards Phase II length and the last velocity measure are more relevant to the musical quality of a retard than the retard length.

Phase I was very varied among the pieces analyzed and no simple rules could be formulated that predicted the timing in this part of the retards. In the model it was realized as a straight line.

The predicted Phase I therefore disagreed considerably from the actual-performances in many cases. It would seem likely that such differences in Phase I contributed to a low rating just as in the case of Phase II. However, timing in retard Phase I is a question which we lieve open for future research. It seems likely that a better understanding on this point may develop from investigations of preretard timing.

Summarizing our findings we can say that the test supported the following conclusions. The descriptive model generates retards that are generally better than straight line retards but not as good as retards actually performed by the players. The model accounts for the dependence of retards on final cadence length, last conceptual unit length and possibly also preretard mean velocity in a reasonably acceptable manner. Nevertheless, great discrepancies between predicted and performed retards regarding Phase II length and last velocity measure seem to decrease the musical quality of the retards.

Concluding remarks

Above we have presented a descriptive model of retards. A fundamental consideration then is to examine the extent to which it has universal application. First of all the model was intended for describing only those retards which occur in motor music. Secondly, we have found reasons to believe that the retards described by the model fit certain instruments only: the correlation found between ratings and preretard mean velocity may suggest that retards are performed with regard to the sound properties of the instrument. These two respects demonstrate some limitations of the model. On the other hand, there is some evidence that suggests a deeper universality of the model. It is notable that retards, although performed by different musicians, did not resist the description by a single set of four equations. What may underlie this consistency? It may be suggested that motor music has associations with a listener's experience with physical motion. The regular sequence of impulses we perceive when we walk or run is rather similar to the regular sequence of beats or shortest units in a piece of motor music. Indeed, the density in time of these impulses has a direct relationship to the velocity of the movement. Note also that it is meaningful to speak about "slow" and "fast" in connection with performance of music.

If our experience with physical motion serves as a frame of reference for a retard, our model must possess a fair degree of generality. Anyway, it may prove rewarding to compare physical motion and retard in future research.

Above we have seen, that the way in which a final retard is performed in a piece of motor music depends on the characteristics of the music (the lengths of the final cadence and the last conceptual unit) as well as of the preretard performance (preretard mean velocity). The dependence on structural properties of the music suggests that the retard has the function of signalling to the listener the structural organization. The mere fact that the final retard occurs at the very end of the piece supports the same conclusion. We may imagine that the cognitive effect of the retard is to announce to the listener that we are now approaching the end of the piece, entering the final cadence, and finally, the last conceptual unit and the final chord of the piece. The fact that timing is used for such a cognitive purpose does not at all appear astonishing. In another form of interpersonal communication by means of sound, i.e. speech, timing has a similar function. Moreover, the mere fact that the durations of the notes deviate systematically in performance from their notated values must lead us to conclude that these deviations carry some information.

The results of the present investigation support the assumption that this information is cognitive.

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References

BENGTSSON, I., GABRIELSSON, A., & THORSÉN, S-M. (1969): "Empirisk rytmforskning", Swed. J. of Musicology 51, pp. 49-118.

CARLSON, R. & GRANSTRÖM, B. (1976): "A text-to-speech system based entirely on rules", Conf. Record 1976 IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, April 12-14, 1976, Philadelphia, pp. 686-688.

LARSSON, B. (1977): "Music and singing synthesis equipment (MUSSE)", STL-QPSR 1/1977, pp. 38-40.