Evaluated rules for the synthetic performance of melodies

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III. MUSIC ACOUSTICS

A. EVALUATING RULES FOR THE SYNTHETIC PERFORMANCE OF MELODIES
W. F. Thompson*, A. Friberg, L. Frydén, and J. Sundberg

Abstract
Starting from a text-to-speech conversion program (Carlson & Granström, 1975), a note-to-tone conversion program has been developed (Sundberg & Frydén, 1985). It works with a set of ordered rules affecting the performance of melodies written into the computer. Depending on the musical context, each of these rules manipulates various tone parameters, such as sound level, fundamental frequency, duration, etc. In the present study the effect of some of the rules developed so far on the musical quality of the performance is tested; various musical excerpts performed according to different combinations and versions of nine performance rules were played to musically trained listeners who rated the musical quality. The results support the assumption that the musical quality of the performance is improved by applying the rules.

INTRODUCTION

It is a well-known fact that musicians contribute importantly to the esthetic experience that a listener may have while listening to a piece of music. This suggests that analysis of music performance is likely to be informative as to some basic requirements for the enjoyment of music. The scientific curiosity for music performance was long kept modest, even though a series of reports were published by Bengtsson & Gabrielsson (e.g., 1983), and it is only recently that the field has started to evoke a more widespread research interest.

The present project was started in the late seventies, and a more extensive review of it will be presented elsewhere (Sundberg & Frydén, forthcoming). The approach of this research has been one of analysis-by-synthesis rather than analysis-by-measurement. Thus, musical performances are generated via computer with the use of various performance rules that act upon a musical score. The development of the rule system is similar to a typical music lesson situation where the teacher tells the student how to better perform the piece of music. In this case a professional musician and teacher of music (co-author LF) has acted as the computer's music teacher.

The software used in this research was originally adapted from a text-to-speech conversion program devised by Carlson & Granström (1975). In our case, the input is the music notation, and the output is the control signals to a synthesizer. Each of the numerous performance rules

can be applied to a musical input, either separately or in combination, and the resultant "performance" can then be judged by musically trained listeners. In this way, the importance of the performance rules can be evaluated.

One might expect that the acceptability of musical performance be a matter of taste rather than of regularity. However, mostly, there has been surprisingly little debate among these authors as to what is an improvement and what is not in our judging of rule effects. Really, this should not be surprising: the fact that music conservatories exist implies that there is a general agreement in the assessment of music performance. Still, there is of course a need to demonstrate the effects of performance rules by statistical means, and this was the goal of the present investigation. The testing was realized in two experiments: four rules were tested in experiment I and five other rules in experiment II.

**EXPERIMENT I**

Introduction

In this experiment, we examined the musical importance in performance of marking phrase boundaries, leap boundaries, the harmonic charge of chords, and the melodic charge of notes. (These terms will be discussed in detail below.) The design chosen allowed an assessment of four possibilities regarding the musical significance of the performance rules.

Support for the first three possibilities would suggest that the performance rules being tested are musically important while support for the fourth possibility would represent evidence against the importance of the performance rules. The four possibilities are: 1) the automatic performance of a melody sounds more musical if one performance rule is applied than if no performance rule is applied; 2) the automatic performance of a melody sounds more musical if a performance rule is applied in addition to other performance rules than if just those other performance rules are applied; 3) although the presence or absence of individual rules may not significantly influence listeners' judgements, the application of several rules in combination significantly improves the musical quality of the performance; and 4) applying arbitrary or counterintuitive rules to a piece of music may significantly improve the musical quality of the performance.

Support for the first two possibilities would strongly suggest that these rules are very important to a musical performance, while support for the third possibility would represent modest support for the importance of these performance rules. Support for the fourth possibility is not expected: the function of performance rules is not merely to prevent a piece of music from sounding mechanical, but to enhance and illustrate various aspects of the musical structure. In other words, performance rules must make musical sense.
Subjects

Twenty musically trained listeners participated in the experiment. Seventeen of the participants were students at the Conservatory of the Swedish Radio, Edsberg. One participant was a doctoral student in the Department of Music, City University, London. Two participants were researchers in the Department of Speech Communication & Music Acoustics, Royal Institute of Technology (KTH), Stockholm and had extensive training in music. Listeners received 100 SEK for their participation in the experiment, except for the latter two participants who were volunteers. Listeners were aware of the general purpose of the experiment but were not informed of the performance rules being tested.

Apparatus and Stimuli

Tones were produced by a DX2l Yamaha synthesizer, controlled by a Macintosh microcomputer via a MIDI interface. A timbre with a small peak at five times the frequency was created by combining three oscillators. This timbre, which had a dull oboe-like sound, was used for all test melodies. Tones had a rise time of approximately 10 msec and a decay time of approximately 60 msec. Consecutive tones were overlapped such that the decay of one tone coincided with the onset of the next tone. Listeners could adjust the overall loudness to a comfortable level at the start of the experiment.

A Le-Lisp and MIDI based music system was used allowing definition and application of various rules that alter the performance of a given piece of music. The program allows music input from a MIDI keyboard, from a file, or by pointing at note symbols with the "mouse". The resulting input is represented in a form similar to conventional notation. The internal organization of the music is in voices of which there may be many. Any of these voices can be selected to be affected by a specific set of rules and subsequently played. A set of rules may contain zero or any number of rules. Thus, a test melody can be played either directly or after a number of rules have been applied altering various note properties such as duration and amplitude. Several macro functions are provided for inserting new rules. Rules can also be used to assign new properties to notes. This means that hierarchical rule structures can easily be introduced as well as features similar to those used in speech research and phonetics. Menus and dialogue boxes are provided, for convenient usage. The program included functions to ensure that the average amplitude and duration of a given test melody was not altered by the application of a rule or rules.

In the input notation, information is included on tempo, phrase boundaries, and chord changes. A special control program was written for running the experiment automatically. It presented the different performances in an order that was randomized individually for each subject and recorded the subject’s answers that were given on the computer.
terminal. The test melodies were heard by listeners through Sennheiser HD 414 headphones.

Procedure and Conditions

Five different test melodies were used to examine four performance rules. These rules were:

1) marking of phrase boundaries by micropauses;
2) marking of leaps by micropauses;
3) marking of melodic charge by loudness and duration; and
4) marking of harmonic charge by loudness and duration.

The four rules as implemented on the Le-Lisp system are as follows:

1. Micropauses were inserted between notes separated by leaps wider than three semitones when the duration of the first note exceeds 250 msec. The micropauses were obtained by letting the decay of the first note start earlier, i.e., by shortening the sounding portion of that note. As without micropauses, tones were overlapping by approximately 60 msec. Introducing a micropause reduced the amount of overlap, see Fig. 1. The duration of these micropauses in msec was four times the magnitude of the leap in semitones. A ceiling was set at nine semitones. The rule was written so as not to operate at the point of phrase boundaries.

2. Micropauses of 80 msec duration were inserted between phrases according to the same recipe as in the rule just described. Appropriate phrasing was decided upon by the authors.

3. Marking melodic charge by loudness and duration. The loudness and duration of tones were increased in proportion to the remarkable-
ness of the note as measured in its "melodic charge". Fig. 2 defines the melodic charge of notes in a C major tonality by means of the circle of fifths. The melodic charge of a note is computed in relation to the root of the prevailing chord. A sound level of the note in dB is increased by a factor of 0.19 times the melodic charge.

Fig. 2. Definition of melodic charge by means of the circle of fifths.

4. Marking harmonic charge by loudness and duration. Harmonic charge of some chords in a C major tonality is shown in Fig. 3. The harmonic charge, $C_H$, is derived from a weighted sum of the chord notes' melodic charges $C_{M,I}$, $C_{M,III}$, and $C_{M,V}$:

$$C_H = 2 \cdot \left( \frac{C_{M,I}}{2} + \frac{C_{M,III}}{3} + \frac{C_{M,V}}{6} \right) - 3$$

The amplitude of the first note after each chord change is increased by the $\Delta L$ reflecting the change in harmonic charge between the chords:

$$\Delta L = 1.5(C_H)^{1/2} \text{ (dB)}$$
Fig. 3. Harmonic charge of various chords. For a C major
tonality the chords would be:

- T C major
- D G major
- S F major
- SS B flat major
- DD D major
- DSR A major
- DTR E major
- SR d minor
- TR f minor
- DR e minor

The intermediate notes are then given intermediate amplitudes so that crescendos and decrescendos are created. Too slow level increases are avoided by starting crescendos not earlier than 1.9 sec ahead of the chord change. Decrescendos, on the other hand, start immediately after the chord change. The duration of each note in a crescendo or decrescendo is extended by a factor $C_{DR}$ proportional to the increase in sound level $\Delta L$:

$$C_{DR} = (1 + 0.018 \Delta L)^{1/2}$$

Chord changes and phrase and subphrase boundaries suggested by each test melody were decided upon by the authors. The principles for creating crescendos and decrescendos are illustrated in Fig. 4.

The excerpts used are listed in Table I. Each test melody was chosen for its appropriateness in illustrating the importance of a particular rule. The marking of phrases, leaps, and harmonic charge were tested with one test melody each. Two melodies were used to test the marking of melodic charge since it was the opinion of the authors that this performance rule was particularly subtle.
Fig. 4. Illustration of crescendos/decrescendos generated by harmonic charge. Above the chord symbols are given in terms of the distance in semitones of the chord's root of the tonic. Below the music, the harmonic charge of these chords are given. The bottom graph shows the resulting changes in sound level.

Table I. Melodies used for testing the rules.

<table>
<thead>
<tr>
<th>Rule</th>
<th>Test Melody</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Marking leaps</td>
<td>J.S. Bach: The fugue theme from the first Kyrie in B minor mass</td>
</tr>
<tr>
<td>2) Marking phrase boundaries</td>
<td>F. Chopin: Waltz Eb major, op. 18</td>
</tr>
<tr>
<td>3) Marking melodic charge</td>
<td>a) F. Chopin: Mazurka No. 5 Bb major, op. 7:1</td>
</tr>
<tr>
<td></td>
<td>b) W.A. Mozart: theme from 2nd movement of Stringquartet, d minor, K.421</td>
</tr>
<tr>
<td>4) Marking harmonic charge</td>
<td>F. Schubert: theme from first movement in &quot;Uncompleted&quot; Symphony, D 759</td>
</tr>
</tbody>
</table>
Listeners heard each test melody under five conditions of rule application. These five conditions were: 1) no rules applied; 2) one rule applied (i.e., the one being tested); 3) three rules applied (i.e., all but the rule being tested); 4) all rules applied; and 5) an inappropriate transformation of the tested rule applied. For the marking of melodic and harmonic charge, condition five used the inverse of the rule being tested. For the marking of leaps and phrases, condition five involved shifting micropauses to random points in the test melody such that they did not mark leaps or phrases.

Presentations were blocked by melody. The five rule conditions of each test melody were presented in a random order within blocks. The order in which blocks were presented was also random. Prior to each presentation, listeners were provided with written instructions, in which they were told to rate the performance of each melody presentation on a scale of 1-9. Listeners were encouraged to compare the task to the teaching of musical performance to children. Thus, their judgements should not be overly critical, but rather should indicate whether the performance was in the right direction. Listeners were told that there were no right or wrong answers, and they were encouraged to use the full range of the rating scale.

RESULTS AND DISCUSSION

Mean ratings of each rule condition for each test melody are listed in the Appendix and displayed in Fig. 5. When test melodies were presented with just the tested rule applied, overall ratings of the performance were significantly higher than when no rules were applied, $F(1, 19) = 25.92, P < .001$. This rating difference occurred for all test melodies, with no significant interaction of the effect with the test melody presented. Thus, the application of each of the performance rules to a strict notational performance of the test melodies significantly improves the musical quality of those melodies.

When all four rules were applied in the test melody presentations, ratings of musical performances were significantly higher overall than when just three rules were applied in the presentations, $F(1, 19) = 8.51, P < .01$. This rating difference occurred for all test melodies presented, again with no significant interaction of the effect with the melody presented. Thus, each of the four rules have a musical importance when other performance rules have already been applied.

Sequences presented with an inappropriate transformation of the rule being tested were given lower ratings overall than melodies presented with the correct application of the rule and melodies presented with no rules applied, $F(1, 19) = 7.87, P < .05$. This finding indicates that performance rules do not improve the musical quality of the piece merely by adding arbitrary variation to an otherwise mechanical performance. Rather, performance rules must be musically sensible.
Fig. 5. Average ratings for the various performance rules tested in Experiment I.

- rule reversed
- no rules
- three rules
- four rules
- one rule

There was one exception to this latter finding. The inverse of melodic charge applied to one of the two pieces used to test this rule yielded quite high ratings. Although not statistically significant, applying the inverse of melodic charge in the Chopin Mazurka yielded higher average ratings than applying the correct version of the rule or applying no rules in this piece.

This finding is understandable if one assumes that under some conditions, listeners may accept a trade-off between noted duration and the desired magnitude of the rule. In the Chopin Mazurka, but not in the excerpt from the Mozart Quartetto, tones with a strong melodic charge were noted with a much greater duration than were other tones in the test melody. Thus, the melodic charge in the Mazurka was, in effect, already well marked by the composer. Applying the inverse of the melodic charge rule may have been heard as a musically appropriate way of making the already obvious melodic charge marks a little more subtle. Nonetheless, when increases in melodic charge were not correlated with changes in duration, as in the Mozart theme, applying the inverse of melodic charge yielded low ratings of the musical performance, while applying melodic charge in the appropriate direction yielded high ratings of the musical performance.

In general, ratings were higher when three or four rules were applied than in other conditions, \( F(1, 19) = 21.09, P < .001 \). However, in three of the five test melodies, the application of just one rule yielded ratings as high or higher than the application of the three other rules.
together. Critical to this finding is the fact that each test melody was used in the experiment because it was particularly useful in illustrating the importance of a particular performance rule. When one rule alone was applied in a performance, this rule was always very important to the performance of the piece. Thus, the finding shows that applying one performance rule that is very important for the piece can be as beneficial to the performance as applying three less important rules.

Listeners often reported having difficulty with the task. Indeed, ratings were highly variable, and when data for individual test melodies were analysed separately, only those concerning harmonic charge yielded all four of the significant differences reported for the overall data (i.e., no rule vs one rule; three rules vs four rules; three or four rules vs other conditions and; an inappropriate transformation of the rule vs no or one rule). The analysis of individual data from other test melodies typically yielded significance in one or two of these four comparisons. Obviously, some of the rules investigated are quite subtle in their individual effects. Nonetheless, overall judgement data showed a systematic relationship between the listeners' evaluation of the musical performances and the presence or absence of the rules.

**EXPERIMENT II**

**Introduction**

Experiment II examined the musical importance of the following five rules:

1) sound level increases with pitch;
2) tempo is increased in ascending motion of melodies;
3) higher notes in leaps are lengthened;
4) short notes are made shorter;
5) short notes are made softer.

This experiment used the same design as Experiment I, and therefore enabled an assessment of the same five possibilities outlined earlier regarding the musical importance of the rules.

**METHOD**

**Subjects**

Twenty musically trained listeners participated in the experiment. Seventeen were students at the Conservatory of the Swedish Radio, Edsberg, Sweden. Most of these listeners had also participated in Experiment I. The other three listeners were at a comparable level of musical training. Listeners received 100 SEK for their participation in the experiment, except for the latter three, who received an extra 100 SEK for travelling time. Listeners were aware of the general purpose of the experiment, but were not informed of the performance rules being tested.
Apparatus and Stimuli

The apparatus and stimuli were identical to those used in Experiment I.

Procedure and Conditions

Five different test melodies were used to examine five performance rules, see Table II. As implemented on the Le-Lisp system, these rules are as follows:

1) Sound level is raised with fundamental frequency by an amount of 3 dB/octave.

2) Tempo is increased in ascending melodic motion by decreasing the duration of each member of the ascending figure by an amount of 5 msec. Each series of two or more rising intervals in a row was considered as an ascending melodic motion.

3) Higher notes in leaps are lengthened. This rule was reserved for leaps greater than two semitones. However, when the leap was part of an alternating pattern of high and low notes, the rule was applied only to the first leap; such alternating patterns are generally heard as two interleaved melodies, while this rule was intended for leaps that are part of one single melodic line. For an interval of 1 semitone's width, the higher note in the leap was lengthened by $\Delta DR$

$$\Delta DR = 5 \times (I)^{1/2} \text{ (msec)}.$$ 

4) Shortening of short notes implying that the duration of quarter, eighth, and sixteenth notes are reduced by 3, 8, and 2 msec, respectively.

5) Softening of short notes: the sound level of a note is reduced by $80/\text{DR (dB)}$, where DR is the duration of the note in msec. For a sixteenth note typically being of 80 msec duration, this rule yields a 1 dB reduction of the level.

Each test melody was chosen for its appropriateness in illustrating the importance of a particular performance rule. Listeners heard each test melody under five conditions of rule application. Except for the fact that different rules were used, these five conditions are identical to those used in Experiment I. For all rules, condition 5 used the inverse of the rule being tested.

Presentations were again blocked by melody. The five rule conditions of each test melody were presented in a random order within blocks. The order in which blocks were presented was also random. Listeners performed the same rating task as in Experiment I.
Table II. Excerpts used for testing the rules in Experiment II.

<table>
<thead>
<tr>
<th>Rule</th>
<th>Test Melody</th>
</tr>
</thead>
<tbody>
<tr>
<td>The higher, the louder</td>
<td>G.F. Händel: Sonata E major for violin and continuo, op. 1:15</td>
</tr>
<tr>
<td>Higher tempo in uphill motion</td>
<td>J.H. Roman: Theme from first movement of Drottningholmsmusiken, IB 2</td>
</tr>
<tr>
<td>Lengthening upper note in leap</td>
<td>F. Schubert: Frühlingstraum, from Winterreise, op. 89:11, D911</td>
</tr>
<tr>
<td>Shortening of short note</td>
<td>F. Schubert: Theme from Trois Marches Militaires, op. 51, D 733</td>
</tr>
<tr>
<td>Softening of short notes</td>
<td>J.S. Bach: Bourree from suite in C major for cello solo, BWV 1009</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

For each test melody, mean ratings for each rule condition are listed in the Appendix and displayed in Fig. 6. Across melodies, ratings significantly differed depending on the condition of rule presentation, \( F(4, 76) = 4.83, P < .05 \). In general, adding a single rule did not significantly influence performance ratings. However, ratings were significantly higher when three or four rules were applied in melody presentations than when just one rule or no rule was applied in melody presentations \( F(1, 19) = 7.24, P < .05 \). To a much greater degree than in Experiment I, ratings from Experiment II were dependent on the test melody presented, \( F(16, 304) = 2.32, P < .005 \).

Analysing the data from each test melody individually, it was found that only one rule appeared to significantly influence ratings on its own. Analysis of ratings given to the Händel Sonata showed that when the rule making higher notes louder was applied, ratings were significantly higher than when that rule was not applied, \( F(1, 19) = 6.27, P < .05 \).

No other rule showed a significant influence on ratings on its own. However, for three of the other test melodies, ratings were higher when either four or five rules were applied than when just one or no rule was applied. This effect was statistically significant for ratings of the Bach Bourree, \( F(1, 19) = 14.89, P < .005 \), and showed a very strong trend in ratings of Schubert's Marche Militaire, \( F(1, 19) = 4.26, P < .05 \). Data from the Roman theme showed a weaker trend in this direction, \( F(1, 19) = 3.54, P = .07 \).
EXPERIMENT II

The latter effects, though providing only modest support for the musical importance of the rules, do conform to informal observations made by the authors. When the magnitude of certain rules is increased to a point that the rule becomes clearly detectable, the performance immediately sounds somewhat pedantic or exaggerated. However, when several rules are used at a nearly subliminal level, the combined effect is musical.

It is, of course, possible that all significant increases in ratings for the four and five rule conditions were due to the presence of the rule making higher notes louder. This rule was indeed able to significantly influence ratings on its own, and it was present in the four and five rule conditions in test melodies used to test other rules. However, this possibility was not supported by an analysis of the extent to which the application of each rule was triggered in test melodies. First, except for ratings of Händel’s Sonata, there was no obvious relationship between performance ratings and the amount of amplitude change introduced by making higher notes louder. Second, there did appear to be some relationship between the extent to which the application of other rules was triggered and whether or not ratings were significantly higher in the four and five rule condition. Thus, while this issue requires further investigation, it is likely that the higher ratings seen in the four and five rule conditions were due to the combination of rules applied, rather than to the presence of one particular rule.
GENERAL DISCUSSION

The rules tested were based on extensive musical experience and music teaching by one of the authors (LF). From a psychological standpoint, it is unlikely that they all share a common psychological base. Thus, it may be useful to interpret and distinguish the rules in terms of their underlying processes. For the rules examined in the present investigation, we offer some tentative suggestions in this regard.

The rules examined in Experiment I may be understood in view of the current knowledge of the cognitive organization of musical structure. As argued, one important function of performance rules may be to articulate and enhance the structure in the music that is being performed. The use of micropauses to mark phrase and leap boundaries may be understood as a performer’s illustration of grouping principles. The grouping of tones into phrase structure involves numerous cognitive factors, including Gestalt principles, and harmonic and rhythmic factors. Subordinate to this level of grouping are subgroups formed by individual factors (Sundberg & Lindblom, 1976; Lerdahl & Jackendoff, 1983). The use of micropauses between tones separated by leaps illustrates the musical significance of subgroups determined by the principle of pitch proximity.

The marking of harmonic and melodic charge may be understood as performers’ way of signalling their sensitivity to key relationships. Thus, structure at the level of keys is reflected in the performance both at the level of musical chords and at the level of individual tones. The interrelationship between these three levels of musical structure has been discussed by Krumhansl, Bharucha, & Kessler (1982) and by Thompson & Cuddy (1986) among others. The latter authors also reported an asymmetry of key relationships depending on the direction of key change analogous to the asymmetry assumed in the rules for marking harmonic and melodic charge.

The rules tested in Experiment II may be understood in view of the current knowledge of pattern perception, or simply as musical expectations based on a knowledge of the physical relationships associated with musical instruments.

The performance rule that shortens short notes has the general effect of sharpening durational contrasts. Contrast enhancement is well known as a fundamental principle in the visual system (e.g., Hartline, 1949; Hartline & Ratliff, 1957; Ratliff, 1965), and is also implicated in the system that handles incoming pitch information (Carterette, Friedman & Lovell, 1969; Houtgast, 1972; Deutsch, 1973). The enhancing of durational contrasts in a musical performance is consistent with this standard perceptual principle.

The main purpose of making short notes softer was to avoid what we have termed the "machine gun" effect, which occurs if a string of short notes is played without care to reduce the overall loudness. Note sequences for which this rule was primarily intended are usually charac-
characterized by good continuation. As well, because the notes of such sequences are short, they are proximal in time to the other notes in the sequence. Considering these factors, the perceptual process of grouping may be nearly optimal under such circumstances. When such strong grouping occurs, the rule may be needed to compensate for a perceptual trade-off between the size of the group and its perceived loudness. A perceptual trade-off between duration and loudness within individual tones has been discussed by Fraisse (1982), and is especially important in harpsichord playing, where the only means of accenting is in the temporal domain. Assuming that this trade-off also occurs at the level of melodic groups, it is perhaps not surprising that strongly grouped tone sequences sound disproportionately loud (like a machine-gun) unless the group members are somewhat softened.

The rule in which higher notes are made louder may have a basis in the physical characteristics of many instruments, and most notably the human voice. An increase in voice fundamental frequency is associated with an increase in sound intensity both in normal speech (Fant, 1968) and in singing (Bloothoof, 1985). Thus, the rule may fulfill a general expectation which has developed through repeated exposure to this relationship between frequency and intensity.

The remaining two rules are more difficult to interpret, but are interesting in that they both have the effect of enhancing the rule that makes higher notes louder. Increasing the tempo of uphill strings of notes will also increase the rate of amplitude change imposed by the rule that makes higher notes louder. The former rule may also act to compensate for a perceptual trade-off between loudness and duration. When higher notes are made louder without altering the duration from that notated, uphill climbs sound laboured. Thus, increasing the tempo of uphill climbs may complement the rule that makes high notes louder by enhancing changes in loudness, while avoiding the sense that the uphill climb is tiresome.

Lengthening higher notes in leaps also enhances the rule that makes higher notes louder, again if one assumes some functional equivalence between duration and loudness. This rule was primarily intended to act upon leaps that are best interpreted as part of a melodic group (melodic leaps), rather than leaps that may occur when two melodies are interleaved. Adding duration where melodic leaps occur may function to strengthen the perceived connection between the two notes. As demonstrated by van Noorden (1975), the streaming of tones into two parts becomes less likely to occur as the rate of alteration between tones is reduced. Thus, where a melodic leap is meant to be part of the same grouping structure, lengthening the higher note may help to convey this grouping.

In some cases, the analysis of data from individual melodies yielded weak effects, suggesting difficulties in isolating and verifying the musical importance of some individual performance rules. It is of course difficult to draw strong conclusions when the effects are weak.
and it is not established how reliably listeners agree on the musical quality of live performances. Part of the difficulty may be that the term "musical" is not clearly and consistently understood by listeners. Therefore it is encouraging to observe that listener agreement was often quite high. Still, it would be possible and helpful to seek corroboration of performance rules also in measurements of actual performances, supplemented by experimentation involving musical judgements by musically competent listeners.

The experiments reported here suggest that musical performances may involve an implicit understanding of several performance rules. As the present investigation considered only nine such rules, numerous other performance rules have yet to be psychologically tested.

ACKNOWLEDGEMENTS

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REFERENCES


Hartline, H.K. (1949): "Inhibition of activity of visual receptors by illuminating nearby retinal areas in the Limulus eye", Federal Proceedings 8, p. 69.


APPENDIX

Mean ratings for each condition of each sequence (standard deviation given below each mean)

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>inverse</th>
<th>0 rules</th>
<th>1 rule</th>
<th>3 rules</th>
<th>4 rules</th>
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<td>4 rules</td>
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<tr>
<td>Mozart (melodic charge)</td>
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<td>Kyrie (leaps)</td>
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<td>4.50</td>
<td>5.20</td>
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