The Effect of Tonal Structure on Rhythm in Piano Performance
Author(s): C. L. MacKenzie, D. L. Vaneerd, E. D. Graham, D. B. Huron, B. L. Wills
Published by: University of California Press
Stable URL: http://www.jstor.org/stable/40285361
Accessed: 06/10/2010 17:37

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/page/info/about/policies/terms.jsp. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/action/showPublisher?publisherCode=ucal.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

University of California Press is collaborating with JSTOR to digitize, preserve and extend access to Music Perception: An Interdisciplinary Journal.
The Effect of Tonal Structure on Rhythm in Piano Performance

C. L. MACKENZIE, D. L. VANEERD, E. D. GRAHAM, D. B. HURON, & B. L. WILLS
University of Waterloo

The effect of tonal structure on rhythm in piano performance was examined. Although music structure is viewed as having rhythmic and tonal aspects, the tonality of a score might alter the rhythm in performance. Five skilled pianists sight read short segments of music under different tonal conditions. Timing in performance was monitored, and the variability of successive intervals was used as a measure of rhythmic precision. Results indicate significant differences between tonal and atonal conditions for the rhythm in performance. Possible explanations are considered, including the past experience of the pianists, expression in performance, biomechanical transitions, and other aspects of music structure visible from the score.

A definition of music from Webster's Dictionary (1980) is "the science or art of ordering tones or sounds in succession, in combination and in temporal relationships to produce a composition having unity and continuity." Although this definition is accurate, it does not convey all that music is, especially when considered in terms of music performance.

A performer sight reading music must translate the symbolic musical score, which has a rather definite structure, into sound that a listener identifies as being an interpretation of the score (as intended by the composer). This task appears at first to be a rather straightforward problem. However, there are many factors that can and do affect the performer's translation of the music: aspects of musical structure (including tonal, harmonic, rhythmic, intensive, and expressive components), characteristics of the performer (such as motivation, anxiety, intentions, level of expertise, knowledge base, perceptual and motor structures, anatomical and biomechanical

Requests for reprints may be sent to C. L. MacKenzie, Department of Kinesiology, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada.
constraints), and other factors including characteristics of the musical instrument and acoustic environment.

Tonality is described in Grove's Dictionary of Music (1980) as "...the relationship of notes and chords to a reference point, this point is called the tonal centre or tonic of the key of music." By far the most predominant type of music in all cultures is structured about a central chord or pitch—music called by theorists "tonal music." Most Western music is based on diatonic scales (seven notes in one octave), the most popular being the major and minor scales. Scales contain specific patterns of whole tones and semitones between certain of the notes. Thus, notes within the major or minor scales are not considered equal, that is, there are some notes that are thought to be more important than others. A key signature indicates the use of one scale for tonal music's basic material and accepts certain relationships between the notes of the scale and the chords built with them. Thus, tonality is regarded as certain accepted (or conventional) relationships between notes of differing importance within the basic scale on which a piece of music is based. Also, the harmonic and tonal structures in a piece of music, being based on the same scale, are closely related.

Another aspect of music performance is rhythm. Rhythm may be defined as the regular organization of music (or sound) with respect to time. This results in each note having a relative time relationship with respect to other notes in the music (rhythm). This time relationship is established (in theory) by the time signature, the tempo, and the placement of the bar lines in the score. There have been studies that have examined the effect of tempo on rhythm (Clarke, 1982; Povel, 1977; Wagner, 1971). Also Sloboda (1983) examined the effect of different bar line placement on the ability of performers to convey the rhythm of the music to listeners. These researchers have provided empirical support for the importance of these characteristics for rhythm.

It appears that tonal/harmonic structure and the rhythmic structure are interdependent; that is, if a tonal structure exists for notes in time there is inevitably a rhythmic structure. Some studies have indicated that listeners can separate rhythmic and tonal/harmonic structures (Longuet-Higgins & Lee, 1981; Steedman, 1977; Longuet-Higgins, 1976). However, Longuet-Higgins suggests that although the perception of rhythm and melody (tonal structure) may be separate processes, a higher level cognitive process will use both perceptions to reveal musically important relations between rhythm and tonality. These relationships may in fact be quite important in correctly interpreting the rhythm in a piece of music, however the rhythmic structure may be all that is required to determine the meter or rhythm of a melody. If these processes are separable to some degree it would seem possible for a skilled performer (who fully understands tonal structure in music) selectively to attend to the rhythmic structure of a piece in order to play the
score accurately. This may be very important in the performance of rhythmically difficult pieces, especially if the tonal relationships are simple.

There is one further aspect of performance important for this study: musical expression. If a performer literally translated the musical notation of the score into sound or music each time he/she performed, this would lead to many identical and sterile performances. Artistically and aesthetically it would probably not be very interesting or pleasing if all performances of a particular piece were the same regardless of the performer. However, the score is not an exact set of programmed instructions for performance. Only to the novice does it appear that a musical score dictates every imaginable performance aspect. A skilled performer is able to play that which is specified by the score while adding much not appearing on the written score. In this way, music resembles a language in that it has a syntax and semantics (Shaffer, 1981) or structure, which once understood may no longer require as much attention. More attention may, therefore, be focused on expression. In order for that expression to be used effectively to enhance the performance, a performer must have a firm grasp of music structure. This may be obtained through experience. Sloboda (1983) indicated that the performer may develop a “dictionary” of expressive techniques and that experienced pianists will use expression often and in a consistent way. Musical expression may be summed up as a complex interaction of the performer’s musical ideas and experience as well as the structure of music.

Given the above aspects of musical performance, one may question how the structure of music affects its performance. In order to answer a question of this nature, one must be able to measure music performance. One approach is to measure rhythm; since rhythm is integral to music performance and skilled performers must have the ability to maintain the proper rhythm in order to be successful, this appears to be a good choice. Other studies that have measured rhythm have used measures such as note duration and internote interval (MacKenzie, Nelson-Schultz and Wills, 1983; Sloboda, 1983; Clarke, 1982; Shaffer, 1981; Povel, 1977; Wagner, 1971). Rhythmic deviations from strict metricality, therefore, are those time intervals that differ from that implied by a literal interpretation of the score. Such rhythmic deviations may be determined statistically using standard deviation (SD) or coefficient of variation (CV) as a measure of dispersion.

This study examines the effect of tonal structure on the rhythmic performance of highly skilled performers. Of studies that have noted the effects of music structure on rhythmic performance (MacKenzie et al., 1983; Clarke, 1982; Nelson, 1982), few have attempted to manipulate musical structure as an independent variable. In this study, two structural conditions were employed: a normal or “tonal” condition and an altered or “atonal” condition. It is hypothesized that pianists will play the “atonal” condition with less rhythmic deviation than the “tonal” condition. This is
expected because the disrupted tonal information will result in a more metrically precise and consistent (or "dead-pan") performance of the score. Two reasons for this are (i) the performer will increase attention on the rhythmic structure, if indeed the tonal and rhythmic structure are separable to some degree (i.e., since the tonal information lacks structure the performer may attend more to rhythmic information) and (ii) less tonal structural cues are available for expression, making the instructed task of playing without expression easier for the performer. Therefore, a more literal performance is expected in the atonal than in the tonal condition.

Method

Subjects

The pianists were five volunteers, ranging in age from 21 to 41 years, from the Waterloo area. The subjects had Grade 10 or ARCT level piano at the Royal Conservatory of Music (Toronto). All subjects were excellent sight readers and were actively involved in regular practice of their instruments at the time of testing.

Monitoring System and Musical Scores

A recently developed piano monitoring system (PMS) was used to monitor the performances of the subjects (this system is more completely described in Wills, MacKenzie, Harrison, Topper & Walker, 1985; Graham, 1984, 1985). Briefly, the PMS includes a Kawai acoustic grand piano interfaced with a PC microcomputer which monitors and stores the positions of the keys as a function of time. The keys are monitored from below on the keyboard with infrared sensors. The system is unobtrusive; one cable emerges beneath the keyboard and neither the action of the keys nor the sound of the piano is altered. The performance setting is thus relatively uncontrived, with little evidence that performance is being monitored. For the purpose of this report, the position–time information for the piano keys was reduced to internote intervals (INI), operationally defined as the time from one key down to the subsequent key down.

The music was a shortened section of the score of Haydn's Sonata 32 in B minor Opus 18, No. 6 (1776) (see Figure 1). This was considered to be a fairly representative piece of tonal music. In addition, with transposition the section could be easily altered tonally without causing major changes to the fingering. The score was shortened by removing the fifth and sixth measures, moving the seventh measure to the position of the fifth, and ending the section after the eighth measure. This six measure score represents the "tonal" condition (Figure 1A). A transmutation of this score to disrupt the tonal/harmonic relationships provided the "atonal" condition (Figure 1B). This atonal transmutation was achieved by rewriting neighboring groups of pitches to ensure that they could not be fitted within a single diatonic key. This was accomplished by frequent use of tritone, major seventh, and minor ninth intervals. The music for both conditions was hand copied with all expressive markings except for the phrase markings, which were omitted. Also, a full fingering scheme was provided in order to ensure all subjects used the same fingerings.

Procedures

All testing took place in a music studio, with each subject tested individually. Subjects gave informed consent for the monitoring of their performance on the keyboard and with audio tape. All procedural instructions were standardized and read. Subjects were told that
Fig. 1. Stimulus music used in the tonal condition (A) is a six-bar section derived from Haydn's Sonata in B minor. With transmutation, the harmonic/tonal relationships were altered for the atonal condition (B). The 10 note segments monitored for analysis are enclosed in boxes. See text for details.
they would be asked to play short segments of music a number of times. Questions regarding the purpose of the experiment were deferred until after the test session. The pianists were asked to be seated comfortably at the piano and familiarize themselves with the piano by playing scales. After this warmup, subjects received one of the tonal conditions (randomly assigned) and were asked to practice the piece with the exact fingering specified. After the 4-min practice, subjects were to play the piece at a moderately fast tempo specified by a metronome (at 88 beats/min, 1 beat = quarter note). This tempo was presented as an 8 count before each of five trials, and the subjects were instructed to begin playing any time after the metronome stopped. This was then repeated for the other tonality condition.

The computer monitored key position–time data for one segment of the music (framed in Figure 1). In each condition, the 10 notes monitored were all sixteenth notes and were played with the right hand alone. Although the segment of music monitored cannot be considered atonal, it is embedded within a larger tonal or atonal piece of music. It was not indicated to the pianists which section was monitored.

Data Analysis

The PMS includes software that extracted the key down position of each key at the end of its trajectory; the time was recorded for each of these positions. Internote intervals (INI) were defined using “down” times of consecutive keys. The first and last notes of the monitored segment were eliminated to avoid an effect noted by Povel (1977): first and last notes of the piece were significantly longer than others. Although this segment of music is embedded in a larger piece, it is separated by a rest at the beginning and by the fact that only the right hand is playing.

From the INIs, descriptive statistics including mean INI, standard deviation (SD) of the INI, and coefficient of variation (CV) of the INI were calculated for data collapsed across position within a trial (indicating rhythmic deviations across notes). Mean INIs were computed for data collapsed across trials for each position. These data were subsequently analyzed with a 2 × 5 (tonal condition × trial) repeated measures analysis of variance for the dependent variables, mean INI, SD of INI, and CV of INI (computed across position), and then a 2 × 7 (tonal condition × position) repeated measures analysis of variance for the dependent variable, mean INI. The analyses for dependent variables computed across position within a trial arc considered first, as they are most likely to reveal rhythmic differences of interest between tonal conditions.

Results

The 2 × 5 (tonal condition × trials) repeated measures ANOVAs for the mean INI, SD of INI, and CV of INI (collapsed across position) revealed there were no significant differences in the mean INIs between the two tonal conditions. This indicates that the tonal and atonal conditions were played with similar tempos. Since the means are of similar magnitudes, the standard deviations alone could be used as an accurate measure of consistency or variability.

The analysis for SD of INI indicated that there was a significant difference in the variability between the two tonal conditions, F(1,4) = 18.79, p < .05. The CV of INI analysis confirmed this significant difference in variation F(1,4) = 26.36, p < .01. Figure 2 shows this effect for the SD of INI and indicates that the atonal condition was more variable. All subjects showed greater rhythmic deviations in the performance of the atonal condi-
tion, and this difference appeared to be substantial for four of the five subjects. Inspection of the individual subject's SD of INI and CV of INI did not reveal further information about the difference. These results are contrary to those expected, indicating that subjects were more consistent in playing the tonal condition than the atonal condition.

The $2 \times 7$ (tonal condition $\times$ position) analysis of variance for mean INI revealed a significant position effect $F(6, 24) = 9.15, p < .001$, which indicated that some INIs were significantly different from others. That is, not all intervals between the sixteenth notes were the same. More importantly, a tonal condition by position interaction $[F(6, 24) = 5.67, p < .001]$ was seen, indicating that the INI patterns were not the same in both conditions (see Figure 3). The greater variability in INIs over position in the atonal condition (reported above) is reflecting mean INI difference at positions five and six (refer to Figure 3). Here the atonal condition INIs undergo a greater change. The notes bordering these positions are apparently being played differently between the two conditions by subjects in all trials. At this point, the atonal condition shows an exaggeration of the short–long pattern typical of all INI pairs. The patterns of mean INIs in Figure 3 are representative for all subjects, that is, the INI of the atonal condition shows a greater increase from positions four to five and a greater decrease from positions five to six, whereas the tonal music shows a small increase from positions four to five but shows only a slight or no decrease from positions five to six.

![Fig. 2. Variability of internote intervals as indicated by the standard deviation for each subject (computed over notes for each trial). For all pianists, the atonal condition is played with greater variability than the tonal condition.](image-url)
Fig. 3. The timing pattern in the tonal and atonal conditions. Note that the internote intervals show greater variation over position in the atonal condition. This is caused by changes in INI over positions 4, 5, and 6.

Discussion

The findings of this study are in direct opposition to the proposed hypothesis. It was argued that the disrupted tonal structure in the “atonal” condition would give rise to greater rhythmic consistency in performance.

The results indicate that in the “tonal” condition music was played with more rhythmic consistency than in the “atonal” condition. The lack of significant difference found in the mean INIs between conditions indicates that the subjects were playing both tonal and atonal conditions at a similar tempo. Therefore, the differences observed cannot be attributed to changes in playing speed. The significant finding of a tonal condition × position interaction on mean INI indicates that the cause of the increased variance in the atonal condition may be attributed to the departure from the usual short–long pattern of INIs at positions 4, 5, and 6.

A number of possibilities might be considered as reasons for these observed rhythmic differences between tonal conditions, including note grouping or phrasing, biomechanical differences (fingers used, placement of the hand on the keys, and differences in key distance), and of course cognitive aspects of tonal condition. The fact that the (rhythmic) notation and phrase marks were identical in the two conditions suggests that this is not the reason for differences in rhythmic performance. It is important to point out here that the analyzed segment of music was played with the right hand alone and therefore can only be considered tonal or atonal within the context of the music in which it is embedded.
With respect to biomechanical factors, if the differences in INIs were solely a function of fingering combinations, one would expect the same effects in both tonal conditions and across INIs produced with identical fingering. However, Figure 3 shows that this was not the case: position 2 involves the same fingering transition as position 6. The effects of differences in hand placement and key distances may be considered as a cause for the rhythmic differences between tonal conditions. However, slight changes in hand placement can make the difference in key distance negligible. Therefore, the changes seen in the INIs between the tonal conditions were probably not caused by slight differences in hand placement. Although these biomechanical interactions are complex, the differences are small and would not be expected to cause major rhythmic difficulties for the experienced keyboard players used in this study.

It appears then that differences in rhythm may be a result of the experimental manipulation of tonality. The question now becomes: why is this so?

One possibility is that the greater variability in the atonal condition reflects the fact that the pianists are less accustomed to sight reading “atonal” than tonal music. Just as less skilled subjects play a tonal piece of music with greater variability than pianists with greater expertise (MacKenzie et al., 1983), it may also be the case that pianists of a certain skill level perform atonal music with greater variability than the performance of tonal music. This suggests that the sight-reading performance involves high-level cognitive processing relating to the performer’s knowledge of tonal structure. Further research might examine novice–expert differences in the effects of tonal (and other aspects of) structure in music.

Another aspect of music performance that may vary as a result of changes in tonal structure is expression. Sloboda (1983) has indicated that performers use expression to convey rhythmic information to listeners. Shaffer (1981) has also noted that music structure affects expression, which in turn controls timing (rhythm). These studies both used tonal music. It is possible that the tonal structure of music is necessary for expression and that some amount of expression is necessary in order to maintain a consistent rhythm. Differences in rhythmic variability in the present study may be due to the performer’s unsuccessful attempt to use expression for the “atonal” condition; the distorted structural cues may lead to inappropriate expression. This offers an explanation for the rhythmic differences observed between sets of tied notes of the two conditions. The performer is able to play tied groups correctly, but between tied groups the rhythm breaks down. It would be necessary to examine larger pieces of atonal music to determine if expression is chunked or grouped according to the grouping of the notes in the score. It may be that the use of expression masks or “ties together” the grouped sections in tonal music. The interac-
tion between expression and tonal structure may allow the performer to play a flowing melody that sounds continuous. The distortion of this structure may reveal an underlying grouping or chunking process in music performance.

The tonal structure of music may be important for expression and more fundamentally it may be necessary for interpreting rhythmic structure. Tonal structure is a source of information to the experienced performer indicating how the notes are arranged. This information may be important for the performer in determining or attending to the rhythm. It is this interaction of tonal and rhythmic structure that may be necessary to play with rhythmic consistency suggesting a higher level process (Longuet-Higgins, 1976). The performer's experience with tonal music is also important to this interaction, in order to use tonal structure one must understand it.

In the present study, the findings suggest that tonal structure affects rhythmic aspects of performance. This may result from the performer's use of structural (tonal) cues for expression in performance. The skilled performer appears to use expression in order to convey rhythmic information to the listener (Sloboda, 1983). Therefore, it may be that the tonal structure is important for the performer's use of expression in conveying rhythmic information in performance. It is this complex interaction of performance parameters that makes music interesting, exciting to listen to, and difficult to study.¹

References


¹ Support for this research was provided by Conrad Grebel College, The University of Waterloo, and a grant to the first author from the Natural Sciences and Engineering Research Council of Canada.


