The influence of musical context on tempo rubato

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Abstract

Different pieces of music offer different expressive possibilities. Even a single piece of music offers the possibility to be treated in several expressive ways (see “Repp (1998)”). How much of this variety of possible interpretations is exhibited in actual performances of the music? Do pianists make use of the different parameters of the piece to shape their performance? Do variety in performances and variety in musical parameters relate to each other? Previous studies stress the relation between timing variations and musical structure (see “Clarke (1985)”), but provide no clear answer to the freedom that is allowed within this regularity, especially when multiple structural descriptions play a role simultaneously.

In an experiment the melody of *Variations on an Original Theme* (Op. 21, No. 1) by Brahms, is set in different musical contexts derived from the Theme. Three pianists are asked to perform the melody in the different settings from a score. They repeat each performance several times. The settings are 1) the melody without bar-lines, 2) the melody with bar-lines, 3) the counter-melody, 4) the melody with the counter-melody, 5) the melody with block chords, 6) the Theme. The Theme contains all material of previous settings (the melody, counter-melody and block chords). The settings are presented in a fixed order and the pianists do not know the pieces before hand.

Analysis of the recorded performances shows that pianists change the onset timing of the melody with respect to the musical context in which the melody is presented. Aspects of the context are imbedded in the timing pattern in different ways; for example, the addition of chords often causes a lengthening of the melody notes with chords, and the addition of a counter-melody constrains the lengthening of a melodic ornament. The melody proves to be the primary expressive source, while chords and a counter melody are good second ones. Both the variety in timing patterns and the extent of tempo rubato appear to increase with increasing complex conditions.

I Introduction

I.1 The performer's expression of music

When a pianist performs a piece of notated music (s)he translates this notation into actual tones sounding in time. Three primary factors are responsible for how the performance will sound: the composition represented in a score, the expression of the composition imparted by the performer, and the instrument. A traditional score of a piece of Western tonal music specifies the pitches and rhythm of the music, and indicates roughly the articulations, dynamics, and tempi of the performance. Other "givens" in the composition itself include the musical texture and, to some extent, the overall character of the music. From the combinations of pitches and rhythms the performer interprets the harmonic and melodic function of the notes.

What the performer's expression adds to the composition is a more closely detailed specification of the execution of notes than is given in the score. In performing the score, the pianist decides on the relative loudness, timing and articulation of simultaneous notes, and also refines the globally indicated dynamics, tempi and articulation marks of the composition. The characteristics of the pianist's expression will depend on his/her musical interpretation of the piece as well as motor skills, and is in part a function of perceptual constraints (for a detailed description see "Penel & Drake (1999)").

The pianist's expression has an extremely large influence on the way the performance of a piece will sound. All differences between the ways in which performers produce a sounding piece of music (good/bad, enlightening/depressing, and the like) are due to differences in musical expression and, to a minor degree, to the instrument. This means that most differences between pianists may be seen in expressive variations in timing, articulation and dynamics.

I.2 Previous literature on tempo rubato

Tempo rubato (literally, "stolen time") is the traditional name for variations in the *timing of onsets* (beginnings) of subsequent musical notes. It is a term first used by Tosi in 1723 "Hudson (1994)" in reference to performers' alteration of the expected rhythm of a melody within an underlying base tempo, where time was "stolen" from one note and "repaid". Later it was used to refer to the alteration of the expected tempo of all voices simultaneously "Hudson (1994)". In this latter practice time was "stolen", without the intention of subsequently restoring it "Donington (1963)". Nowadays the usual performance practice of classical and romantic music is to vary all voices simultaneously, slowing them down or speeding them up in more or less the same way at the same time (empirical evidence for this is for example provided by studies of "Repp (1996)", and "Palmer (1996b)"). In other musical genres, such as jazz and authentic historical performance practice, the alteration of the expected rhythm of the melody (to borrow time as "Donington (1963)" calls it) against a steady beat or base tempo is still common use "Ashley (in preparation)".

Sometimes composers or editors indicate tempo rubato, in the sense of gradual tempo changes, in the score of a musical work. For example, *ritenuto* or *decelerando* indicate a slowing of the tempo, while a speeding up of the tempo is typically indicated by *accelerando*. Performers also frequently show a tendency to speed up and slow down when this is not indicated in the score. Such modifications of tempo typically occur in relation to phrase structure, as a way of marking phrase boundaries (see "Palmer (1989)" and "Repp (1990, 1992a)").

Alterations of the rhythm which are not related to tempo *per se* but which affect more local aspects of temporal relationships between notes also occur in the course of the performance of a work. Situations in which certain notes are shortened or lengthened in favour of other surrounding notes are generally not indicated in a score and are part of what musicians refer to as "performance practice". An example of changing the relative timing of notes is the French practice of *notes inégales,* as described from the mid-seventeenth century to the end of the eighteenth century. In this practice, pairs of equally notated notes are performed with a slight lengthening of the first note "Hudson (1994)", "Donington (1963)".

In the research literature of music psychology, music performance has been of particular interest, beginning with the pioneering work of Seashore in the 1920s (see "Seashore (1967)" for a summary). The studies are mainly concerned with Western tonal music for which a score is available. In this research, the kinds of variations that pianists make in onset timings, dynamics, and articulations (= offset timing) are described and explanations for the observed regularities are proposed. One explanation that is quite appealing involves mapping the expressive variations to the musical structure of the piece. In this approach the assumption is made that the performers' expression of the music serves to highlight the musical structure "Clarke (1988)", "Palmer (1996b)", "Sloboda (1983)". In other words, the expressive patterns found in performances of a piece can be explained with reference to the performer's structural interpretation of the piece. In this sense 'the interpretation of a piece of music acts as a grammar generating the expressive forms in a performance' "Shaffer, Clarke & Todd (1985 p.63)".

The kinds of relationships between musical structure and tempo modulations that have been suggested by various researchers include modulations that clarify the metrical structure of a piece, modulations in relation to harmonic structure, and phrase final lengthening. Modulations in relation to metrical structure are suggested by "Parncutt (1994)", and by "Clynes (1995)", who proposes a "composer-specific pulse" which is characterised by a special pattern of relatively longer and shorter beats in each measure. Further, tempo modulations have been suggested to relate to global patterns of harmonic tension and release, as found in "Palmer (1996a)", or more local harmonic phenomena, such as Sundberg's "harmonic charge" "Sundberg, Friberg & Frydén (1991)". Phrase final lengthening is a lengthening of notes at the end of musical groups (or, put another way, a slowing of tempo at the end of a group). It is a common phenomenon, reported by many researchers in speech and music (among others, "Shaffer (1980)", "Todd (1985)", “Palmer (1989)”, “Repp (1990, 1992a)”). In the relation between grouping structure and phrase final lengthening it has been proposed that tempo rubato in musical performance is used to reflect the hierarchic depth of a syntactic unit or group by the amount of slowing or pausing at its boundary “Shaffer (1980)”, “Todd (1985)”. What this means is that a hierarchic grouping structure (for example, small motivic groups combining into phrases, combining into themes) is reflected in the amount of slowing down at group boundaries, with larger-scale boundaries showing more slowing than smaller-scale boundaries.

Local lengthening or shortening of notes is often viewed in relation to certain surface characteristics of the music such as harmonic, rhythmic and melodic contexts of notes. “Sundberg et al. (1983, 1991)” have developed a generative model of expressive treatment of notes in relation to such musical characteristics. The model is based on generalisations of the judgements of a professional musician “teaching” a computer to play expressively. An example of harmonic context in Sundberg’s model is harmonic tension or distance of a note to the tonic, where the duration (and intensity) of a note whose tonal distance is far from the current tonic is increased. Other factors may also affect musically expressive performance. For example, contrasts between the duration of notes is reduced, in such a way that a short note just before a long note is played longer than a short note in between other short notes. Also, the duration of notes just after a large leap is lengthened for expressive purposes in favour of the duration of the note initiating the leap “Sundberg et al. (1991)”.

1.3 Difficulties of previous research

Current explanations of tempo rubato rely heavily on the concept of a *tempo curve*. This notion refers to a changing tempo “path” to which the music is synchronised. One implication of research using the concept of the tempo curve is that these curves have some independence and can be modulated and transposed without regard to the more detailed structure of the work, such as rhythmic or harmonic structure. In this sense a tempo path specifies tempo changes that are natural and general such as the final retard that is suggested to be an allusion to physical motion “Kronman & Sundberg (1987)”. “Desain and Honing (1993, 1994)” plead against this notion of an independent tempo path, and claim that a sense of tempo variation cannot be perceived independently of the events carrying it.

The focus on the explanation of expressive timing patterns by generative models, such as “Todd (1985)” and “Sundberg, Friberg and Frydén (1991)”, gives another bias, that of providing one expressive pattern for one structural description. In other words, the rhythmic, harmonic and melodic features of music are described and coupled with certain expressive patterns of timing or dynamics. In this account no reference is made to a performer who actually makes this translation from structure to sound. Therefore, only one expressive interpretation of the music is provided and differences between performers are not accounted for. Most of the time, the modellers do admit this shortcoming. For example, “Sundberg et al. (1983)” suggest that the rule-system should leave room for variations in the magnitude of the effects produced by the expressive performance rules to model the multitude of choices that are available to musicians. They also suggest that musicians can and should violate one or more of the performance rules in order to surprise or excite the audience.

I.4 The present study

In the present study we aim to compensate for at least some of these shortcomings. First of all, we try to get a grasp on the differences between performances of the same piece. According to “Repp (1992a)”, performances of the same piece show both considerable commonality, as well as diversity, in their timing patterns. The commonality found by Repp existed at a more general structural level than the diversity; commonality between performances mainly concerned phrase final lengthening, while the diversity was found in the expression of melodic gestures of approximately seven notes. The origin of this diversity is uncertain. On the one hand, differences in interpretation of the musical structure would lead to different timing patterns, even when the same strategy is used to translate the structural description into action and sound. On the other hand, it is possible that performers can express the same structural interpretation in different ways, which would also lead to different timing patterns.

In the present study we will try to explain the diversity of performances in relation to the number of possible structural descriptions of the music. In this explanation we assume first of all that there is no single structural description of a piece of music which will be used by all interpreters, but rather that there are multiple possibilities for making structural descriptions of most pieces of music, at some appropriate level of detail. The number of descriptions increases with the complexity or diversity of the music, which leads to smaller similarities between performers. A number of sophisticated studies in music theory suggest or show how this diversity of musical structure might be understood; these include “Meyer (1967)”, “Kunst (1978)”, “Lerdahl and Jackendoff (1983)”, and “Lewin (1985)”.

Second, we will investigate the extent of tempo rubato in a more systematic way than has been previously done. Not much is known about the regularities underlying the ranges of tempo rubato found in musical performance. A general agreement is that the extent of tempo rubato changes with the hierarchic depth of the grouping structure.

There are, however, other regularities that underlie the use of tempo rubato, which have not been investigated systematically. One of these is that the average extent of tempo rubato changes with the type of music being performed. For example, Chopin etudes are frequently performed with a relatively large amount of tempo rubato, while Bach fugues are often performed in quite strict tempo. Musical style, a performer’s personal style, and the performer’s conception of the appropriate way to play a given musical style all play a role in this. We think, however, that musical structure plays an underestimated, but important role as well. Evidence for this is found, for example, in the way a theme and its rhythmic variation--which share many aspects of structure--are performed with different degrees of rubato (see “Desain & Honing (1994)”). Even more striking is the difference in rhythmic freedom with which a prelude and fugue of a harpsichord or organ sonata from the seventeenth century are generally performed. An example of this is the well-known Toccata in D minor by J. S. Bach (BWV 565) in which a fugue is interspersed with sections of free fantasia “Grout & Palisca (1988)”.

To our knowledge it is still unknown which aspects of the musical structure influence the extent of rubato. We do, however, think that there are plausible hypotheses. The idea that we pursue in this study is that the average extent of tempo rubato of a performance depends on structural characteristics of the music and, in particular, on the richness of the musical texture. Our main hypothesis is that a rich musical basis is needed to perform a piece with significant tempo rubato. In this respect we think a melody alone will not typically be performed with large tempo variations, while a melody with chords and arpeggios has more potential to be performed expressively. On the other hand, two melodic lines together could constrain each other in timing freedom due to the interaction of their individual timing profiles. Although we think other issues play a role as well (such as the possible metrical “rigidity” of a piece) we will only deal with influences of musical texture (inferred from the score by the number of voices) and interaction of melodic lines on the extent of tempo rubato.

In the present study, we recorded performances of a melody set in different musical contexts. These settings of the melody vary in diversity of musical structure as well as in richness of texture. The influence of these contexts on the performance is examined, in particular with respect to the variability and the extent of tempo rubato of the performances.

Specifically, we asked three professional pianists to perform the melody of the Theme of Brahms’ *Variations on an Original Theme* (D major, Op. 21, No. 1, 1861) in different musical settings. They repeated each performance several times. The different musical settings are: 1) the melody without bar-lines, rhythmic beams, dynamics and phrase markings; 2) the melody with bar-lines, rhythmic beams, dynamics and phrase markings; 3) the counter-melody alone; 4) the melody with the counter-melody; 5) the melody with block chords; 6) and the Theme as Brahms originally set it (see figures 1-6). The Theme combines all the material of the previous settings (the melody, countermelody and block chords). A more detailed description of the stimuli follows in the method section.

All of these musical excerpts have a very similar grouping and metrical structure; this means that differences in timing of the melody should not be due to differences in these structural aspects. This provides a way of testing the generality of models that map timing variations to grouping and metrical structure without taking other aspects of the music into account such as rhythmic, melodic and harmonic structure. More commonality between the different settings would implicate grouping and metrical structure as a strong influence; less commonality would implicate high influence of other aspects of the musical structures that differ from setting to setting.

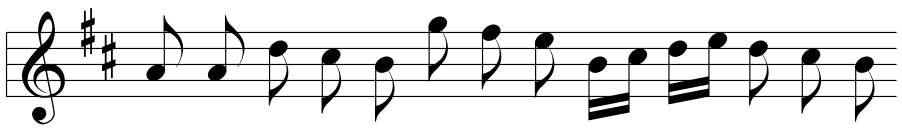

Figure 1
First four measures of condition 1: melody without bar-lines, rhythmic beams, dynamic and phrase marking.

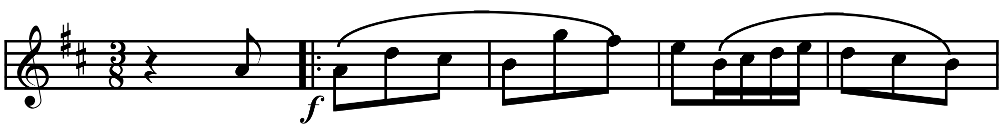

Figure 2
First four measures of condition 2: melody with bar-lines, rhythmic beams, dynamic and phrase marking.

Figure 3
First four measures of condition 3: counter-melody solo.

Figure 4
First four measures of condition 4: melody with the counter-melody.

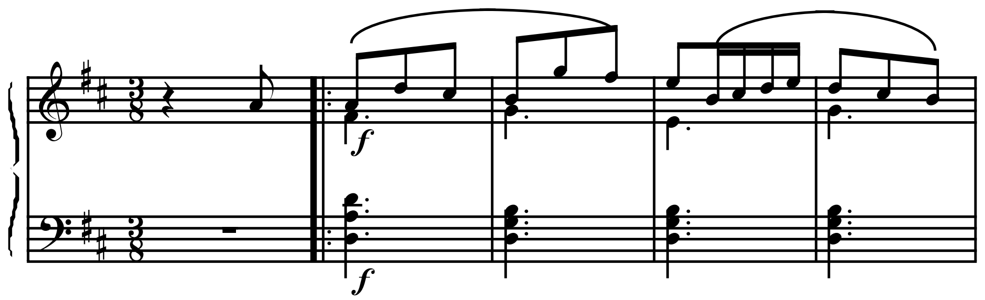

Figure 5
First four measures of condition 5: melody with block chords.

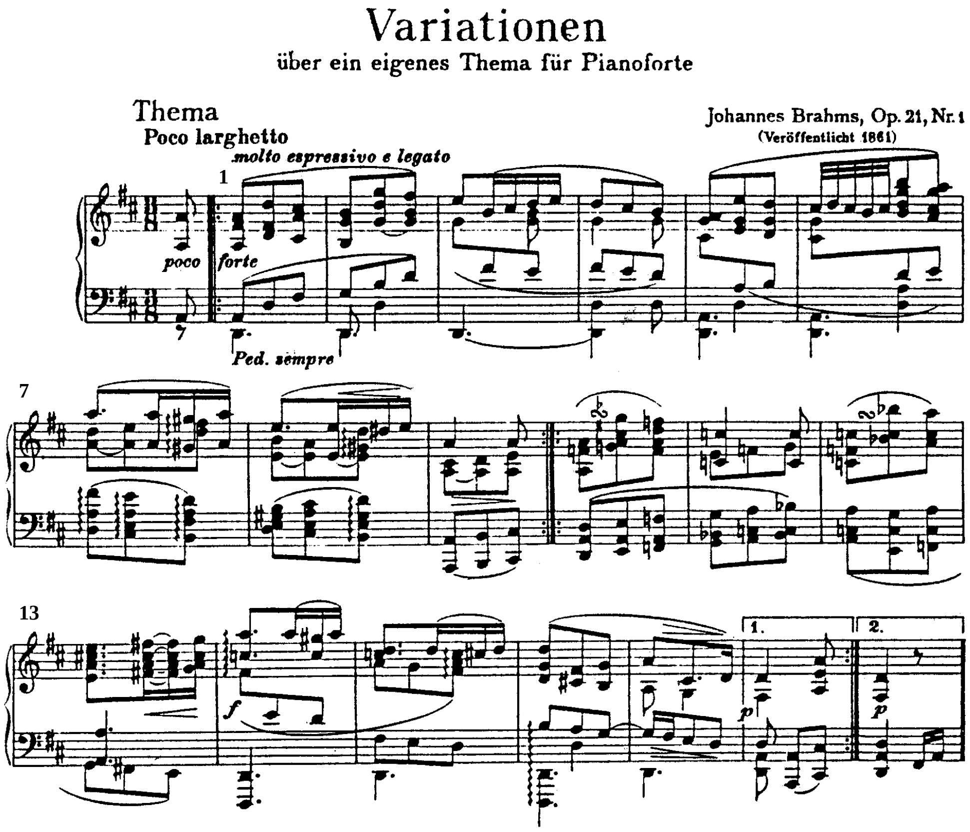

Figure 6

Condition 6: the Theme by Brahms from which all other stimuli are constructed. The melody is the upper line of the Theme. The counter-melody is the upper line of the Bass staff. The chords are the (simplified) chords at each first beat of the measure.

II Method

II.1 Material

The pieces our pianists performed consisted of a melody in different settings. The melody and the settings were (for the purpose of the experiment) extracted from the Theme of *Variations on an Original Theme* for piano solo by Brahms. We chose this piece because, although written by a master composer, it is fairly unknown to most pianists and has interesting structural features such as rhythmic diversity, rhythmic conflicts, unconventional phrase lengths (nine measures), and a combination of chords and several melodic lines. Performers' general unfamiliarity with the piece gave us the opportunity to manipulate the music without the risk of the pianists noticing it and limited the possible confounding effects of prior knowledge of the music.

The settings of this melody vary in texture and complexity. The texture is most impoverished for the melody-alone condition and becomes increasingly rich by combining the melody first with the counter-melody (two voices), followed by the melody with an accompaniment of chords (four voices), and finally is in its richest context of all in the Theme. As an indication of the complexity of a musical context, we take the number of explicit dimensions of the musical structure. This number is small for the melody alone condition, greater for the melody with block chords condition (one melodic line + harmony), great for the melody with counter-melody condition (two melodic lines + harmony) and greatest for the Theme (two to three melodic lines + harmony + arpeggio chords).

To these five settings of the melody, one stimulus is added that does not contain the melody, but consists of the counter-melody on its own. This brings the total of conditions to 6, each containing three repetitions of one stimulus.

In more detail, the conditions can be described as follows.

- In Condition 1, the player is confronted with the melody of the Theme with no explicit metric, phrasing or dynamic information given. The stimulus contains, in other words, only the “raw ingredients” of melody: pitch and rhythm (the first four measures of stimulus 1 are given in figure 1). In this condition there are still a variety of sources of information upon which the performer can draw, however. For grouping structure, there are parallelisms of motivic structure caused by the repeat of the first and second “halves” of the Theme, which indicate large-level grouping. There are individual notes, such as the d’’ and g’’ in figure 1, which are emphasised by being the local maxima of the melodic contour, and there are notes that receive “agogic” or durational stresses, such as longer notes surrounded by shorter ones. However, note that in these cases some of the stresses so indicated go against the actual meter of the melody as notated in the original score. For example, in the first few measures all of the notes that would receive stresses by virtue of being the goal of a melodic leap (e.g. the third note in the melody) occur not on the downbeat but internally to the measure. Such rhythmic and metric conflicts are a typical feature of Brahms’ music.
- The second condition is the same melody, this time presented in its entire form (for the first four measures, see figure 2): bar-lines, time signature, phrasing, dynamics, rhythmic grouping (beams), ornamented eighth notes (in measure 10 and 12 (that is, the first and third measures of the second half). The addition of metric information gives the player much more clarity as to the musical structure of the melodic line. In particular, the location of downbeats--relatively strong beats--are now disambiguated. However, a number of new decisions are now made available, as well: for example, how should the relative weight of the downbeats and the notes emphasised by leaps be handled? There are multiple implications for performance, coming from different aspects of the musical structure, such as meter, phrase and melodic contour, giving the player an interesting set of factors to balance in producing a performance.
- Condition 3 (see figure 3) differs from all others in that it does not include any version of the melody. Instead, it consists only of the counter-melody taken from the Theme. Our intention here is to determine the way in which the counter-melody

would be played expressively if taken by itself, to better understand its contribution to the performance of the Theme as a whole. In fact, there are noticeable differences between the construction of the counter-melody and that of the melody. For example, the most notable “goal” of melodic direction in the counter-melody is on the downbeat of measure 3 (the turning point of the melodic contour)--a point not emphasised in any significant way in the melody. If a performer should focus on this aspect of the music, there might be some timing changes produced with the goal of defining this point in time as significant (for example, slowing down in the vicinity of this beat).

- Condition 4 consists of a two-voice texture, containing the melody and counter-melody played together (see figure 4). It is in this condition that truly interacting sets of musical possibilities begin to emerge, as the related but individual structures of the two lines are presented together. Further, the harmonic intervals are new in this condition. Up to this point any sense of chord, consonance, or dissonance in the music was something that had to be purely inferred by the performer, as there were no simultaneously sounding tones. However, now certain melodic tones--for example, the downbeats of mm. 8, 11, and 17--are mildly dissonant in the new context, affording new possibilities for expression (in this case, perhaps lengthening the tones so as to emphasise the tension of the dissonance).
- Condition 5 is somewhat like condition 4, in that the melody is now placed in the context of other voices. However, this time the melody is presented with block-chords (see figure 5), which is a harmonic differentiation of the melody, with chords and chord functions now quite explicit rather than implicit. This condition also brings a change in texture, because of the fuller sound of the chords. In condition 5 the more dissonant tones are the downbeats of measures 3 and 6, neither of which were dissonant in condition 4. For this reason, different melodic pitches may be emphasised in the harmonic-block chord context of this condition than in the more purely contrapuntal condition 4.
- The last condition is the full Theme (figure 6), which contains the melody, the counter-melody and the chords in full context. This is the most complex piece of music and it has the richest texture. It is the only stimulus composed for musical

purposes by a well-known composer and not for experimental purposes. In this condition we hope to see the way in which the performer chooses from among the different possibilities inherent in the composition, which should have been highlighted in the previous conditions, in order to produce a rich and interesting performance.

The Theme is in D major, in three-eight meter and starts *poco forte*. The first measures of the piece emphasise D major, with the tonic chord in the first measure, sub-dominant chords in measures 2-4 and dominant chords in measures 5-6. From the tonic of D, the music modulates to A major at the end of the first half. The second half starts in d minor, modulates to the relative major tonality of F (mm. 10-11) and returns via the dominant of G (mm. 14-15) to D major (last three measures). The piece begins and ends with a pedal on D and parallel melodic lines in eighth notes. In between the movement is primarily in chords of eighth note duration. Dissonances regularly occur as passing notes and changing notes. Strong dissonant chords occur, for example, at the start of measure 5 and at the last beat of measure 8.

The musical structures of the stimuli are quite similar in several respects. All stimuli have a common metrical and phrase structure, except for the melody without bar-lines (stimulus 1), which has no explicit metric structure. Stimuli 2-6 are in three-eight meter, with an eighth note metrical level and a larger dotted quarter note level; sometimes the eighth note metrical level is subdivided in a sixteenth notes. The eighth notes which are ornamented with a main-note or five-note turn (for a definition see “Donington (1963)”) in measures 6, 10 and 12 occur irregularly, in that they do not fall into a metrical framework other than the eighth note and bar levels.

Stimulus 1 lacks a metrical indication. It is therefore unclear what metrical interpretation the performer will make. The performer may choose between a binary and a ternary meter, which are the most common meters in western classical music, or, possibly, he will change the meter within the piece. The piece could either start on the downbeat, with an upbeat or with upbeats. Cognitive rules like the metrical rules of “Lerdahl and Jackendoff (1983)” provide plausible downbeat markers, such as relative early notes within groups, the note after a leap, a relative long note, a relative low note. For stimulus 1 these rules do not unambiguously show one solution. For example downbeat markers within the frame of the first eight notes would fall on the first note (early note within a group), third note (note after a leap) and sixths note (note after a leap). These last two accented notes preferably receive parallel metrical structure. The first long note is spaced fourteen eighth notes away from the accented note at the sixth eighth note beat. This distribution of accented notes cannot be combined in one optimal way with the metrical well-formedness rules that state that strong beats should be spaced either two or three beats apart and each metrical level must consist of equally spaced beats (see "Lerdahl & Jackendoff (1983)").

All stimuli are divided in two halves (A and B) both of which are repeated in the performance. Each section is nine measures long. Both sections contain two sub-phrases of which the first sub-phrase is built out of a 2 + 2 measure structure, whereas the second sub-phrase consists of a 2 + 3 measure structure. This periodicity is found in both the melodic and harmonic structure of the piece. In section A, both sub-phrases (mm. 1-4 and 5-9) show a rising and falling melodic movement. The start of the second sub-phrase of section A (in measure 5) is marked by a variation of the beginning measures of the piece. In section B, the melody of the first sub-phrase rises towards the start of the second sub-phrase (in measure 14). This second sub-phrase mainly contains a falling movement. In the first sub-phrase of section B the chord progression is in eighth notes, while in the second sub-phrase the pedal on D dominates.

Because all stimuli are derived from the same Theme the global underlying harmonic progressions of the stimuli are the same. It is, however, unclear whether a performer will interpret the underlying harmony in the same way for each stimulus. In the first 4 stimuli only one or two melodic lines are given, which is not enough to present the performer with an unambiguous harmonic context. Slightly different harmonic interpretations of the stimuli cannot therefore be excluded.

II.2 Subjects

Three professional pianists participated in the experiment. They have all completed their undergraduate conservatory-level studies and are presently active as performing musicians. Subject 1 (S1), age mid-twenties, is continuing his studies at an advanced level. Subject 2 (S2,) age mid-thirties, is working as a professional accompanist. Subject 3 (S3), age late-twenties, is a professor of piano at a conservatory. The pianists were paid an appropriate fee for their services.

The analysis of the performances of the pieces by only three pianists provided the opportunity to obtain detailed insights into the treatment of the different contexts by each pianist, without the danger of an overload of data. It also gave the opportunity for (thorough) comparison between the performances. Insight into the diversity between performances of the same piece is limited, because of the small number of subjects. We accept this limitation in favour of a more detailed comprehension of each single performance.

II.3 Procedure

Each pianist participated in a separate recording sessions of one hour including two short breaks. Each recording session had the following set-up. Upon arrival, the pianist was given time to familiarise himself with the laboratory arrangement and to warm up. The first musical fragment was presented to him on a score. The pianist was given time to examine the piece and to study it. A metronome was provided during the practise to help the performer to set the right global tempo of the eighth notes at approximately 60 beats per minute (BPM). During the recordings no tempo indication was given. The instructions were to examine the piece and to play it four times with approximately the same expression. The first time through was meant as a trial, with the other repeats being the actual recordings. The pianist was also asked to play as musically and naturally as possible.

The tempo of the eighth notes at 60 BPM was chosen in accordance with a CD recording of a performance of the Theme by Idil Biret (Naxos CD 8550509). The tempo was appropriate for the Theme, but a bit slow for the simpler first four conditions. By asking the pianists to perform all conditions in approximately this slow tempo, we assured that the tempo contrast between the first four conditions and the last two conditions would be limited. In the experimental design we favoured expressive freedom for the pianists above experimental constraints. We wanted the pianists to play as freely and expressively as possible. The result of this procedure was that they were given a metronome to use during practice and establish a reference tempo, but the metronome was not used during the recording sessions. This made tempo differences between performers and conditions unavoidable, as, without a steady mechanical beat given as a "click track", all performers will tend to drift up and down in tempo over the course of time. The actual average tempi therefore show some differences between conditions and between performers (see table 1). Our reason for being concerned with base tempo is that previous research has shown that timing patterns change when a piece is performed in different tempi "Desain & Honing (1994)", "Repp (1994)". This means that we cannot generalise over tempi, and that tempo can be a factor in determining the timing pattern of a piece.

	Condition 1	**Condition 2**	**Condition 4**	**Condition 5**	**Condition 6**
Subject 1	82.7	84.7	75.4	70.1	54.0
Subject 2	97.5	98.0	110.5	103.3	87.1
Subject 3	79.5	77.6	67.8	59.9	48.1

Table 1
Mean tempo (in beats per minute) per performer per condition.

The stimuli were presented in a fixed order (in the order described above). The stimuli could not be presented in random order because they are transformed versions of a theme and we wanted the pianists to perform each stimulus in as "unprejudiced" a manner as possible. That is to say, the first condition had to be the first stimulus to be performed, as otherwise the pianists would have known the metrical structure of the piece. Likewise, the Theme had to be the last stimulus presented. It was also crucial that the pianists did not know the Theme beforehand (as noted earlier, one of the reasons why this piece was chosen). By presenting the melody with increasingly more information, we ensured that each fragment had its own identity.

The recordings were made in the ‘Music, Mind, Machine’ laboratory on a Yamaha Disklavier MIDI grand piano. This instrument detects key velocities and pedal movements optically and converts this information to standard MIDI messages “MMA (1996)”.

II.4 Analyses

The analysis of the three recordings of the six stimuli from each pianist involved several steps. The MIDI files with the performance data were imported in POCO, a computer environment for research into expression in music (see appendix and “Honing (1990)”). A performance-score-matching facility in POCO was used to link notes in the performance to their corresponding score representation and to extract the timing data from the recordings for the melody of each condition and the counter-melody of condition 3 and 4 “Desain, Honing and Heijink (1997)”, “Heijink & Desain (in press)”. For further processing and statistical analysis of the data the statistical software package JMP 3.2.2 was used.

The timing data consist of scaled and normalised inter-onset-intervals (IOI’s) at the eighth-note metrical level. First the melody eighth note IOI’s are constructed, by calculating the duration between succeeding onset times of melody eighth notes. When there is no melody note onset that coincides with the eighth note beat the interval to the next melody note is interpolated. This eighth note IOI pattern is than scaled to the slowest tempo of all performances (i.e., 54 eighth notes per minute). We divided the IOI’s of a single performance by its mean eighth note IOI and multiplied this by the new, standard mean eighth note IOI (1132 ms). The scaled IOI patterns are finally normalised by subtracting the mean IOI from each eighth note IOI. The result is a timing pattern that indicates for each melody eighth note how much its duration deviates from the mean eighth note IOI. This deviation is given in milliseconds (see figure 7). The same is done for the counter-melody in condition 3 and 4.

The reason for this normalisation and scaling of tempi is that we wanted to have a uniform scale in which all tempo variations can be compared directly with each other, independent from mean tempo of the performances. Both the scaling and the normalisation did not influence the correlation measurements on which the results of the first "Result and Discussion" section are based. They do, however, effect the extent of tempo rubato measurements. This influence is further discussed in section III.2.

We take this approach aware of its possible limitations. In particular, this procedure of scaling the performances seems to imply that one can generalise over tempo, and this is clearly not the statement we want to make. The only reason for scaling is the uniform scale for tempo variations, as far as the explanation of the differences is concerned, tempo is not excluded as a factor (see also III.1.f)

Figure 7
Above: Score condition 5, melody with block chords, measures 5 – 9.
Below: Timing profile condition 5: S1, 5mel, measures 5-9 The duration between succeeding melody eighth note onsets (above) is calculated resulting in an eighth note IOI pattern. This pattern is normalised by scaling the mean tempo to the slowest tempo of the performances. An eighth note timing pattern (below) is calculated by subtracting the mean eighth note IOI from the normalised eighth note IOI pattern. The deviation from the mean in milliseconds is then depicted. When no melody note falls at the eighth note beat, the duration till the next melody onset at an eighth note beat is calculated and divided by the nominal duration of the interval.

We focused on the interpretation of the tempo rubato pattern at the eighth-note level of the melody. By doing this we made two assumptions: first, that tempo rubato is expressed by variations in the length of beats, and second, that beats coincide with the onset of melody notes. In other words, we measure tempo rubato by calculating the duration between onset-times of successive eighth notes. Measuring onset-onset intervals is the most accurate way of measuring tempo variations available.

The choice of the eighth note level is made, because, on the one hand, this level is small enough to contain detailed tempo variations, which provides the opportunity for performer differences to come through, and the other hand, it is the “tactus” level--that from which the performer is feeling the ongoing “pulse” of the music. By focusing on the tactus level we expect that inconsistencies due to lack of motor and conceptual control play a minor role.

III Results & Discussion

The following section is split in two. First we will report the results of the study in relation to the timing contour of the melody in the different conditions for the different subjects, and then we will report the results as far as they are concerned with the extent of tempo rubato.

We use two kinds of abbreviations: 1) S1, S2 and S3 for respectively subject 1, 2 and 3; and 2) a combination of a number and "mel" or "counter-mel" refers to the timing data of either the melody or the counter-melody from a certain condition. For example, 4mel refers to the timing of the melody in condition 4, while 4counter-mel refers to the timing data of the counter-melody in the same condition.

The focus is on the analysis of the onset timing of the melody in the different conditions. At one point in the analysis, however, we will also consider the onset timing of the counter-melody. In these analyses only the performances of S2 and S3 are taken into consideration. We leave out the analysis of the counter-melody by S1, since the recording of the performance of condition 4 by that subject showed some missing notes in the counter-melody due to very soft playing, which the Disklavier did not register.

Remember that all timing patterns are scaled to the lowest tempo. This results in relatively large tempo variations. The actual tempo variations can be reconstructed with the aid of table 1. The effect of the scaling is only noticeable in the figures that show timing deviations in ms. The correlation measurements are the same for raw IOI's as for scaled and normalised IOI's.

III.1 Changing timing contour

In general we found that the variability in timing contour is largest between performers, moderately large between conditions within performers, and smallest within conditions and within performers. The average correlation between timing profiles (= eighth note IOI) of repeated performances is 0.81, which means that the effect of repetition on the tempo rubato patterns is small (for further detail see table 2). Generally the correlations between eighth note IOI's of the melody in the different conditions were lower than the correlation between eighth note IOI's of repeated performances. Significant differences between correlations are for example the low correlation between performances of 2mel and 4mel by S3 in contrast to the consistency with which 2mel and 4mel are timed over repetitions[1]. Taken as a whole, these results indicate that the contexts effect the rubato patterns more than the repeats do. In other words, subjects do change the timing of the melody with changes in context. This change occurs, however, only to a limited degree (the correlation between tempo patterns are all significantly greater than 0 ($p < 0.05$); for an overview see table 3).

Performer	Condition	Average correlation between repetitions
S1	1mel	0.864
	2mel	0.756
	4mel	0.834
	5mel	0.859
	6mel	0.788
S2	1mel	0.890
	2mel	0.793
	4mel	0.888
	5mel	0.850
	6mel	0.882
S3	1mel	0.546
	2mel	0.750
	4mel	0.741
	5mel	0.713
	6mel	0.836

Table 2

Average correlations between repetitions split by performer and condition. The correlations are the same for scaled, normalised and raw eighth note IOI patterns.

Variable	S1 1mel	S1 2mel	S1 4mel	S1 5mel
S1 2mel	0.753			

[1] Differences between correlations were calculated with the aid of a test for the comparison of correlations as described by "McCall (1990)", p. 230-234.

S1 4mel	0.616	0.769		
S1 5mel	0.532	0.714	0.718	
S1 6mel	0.492	0.644	0.600	0.821
Variable	**S2 1mel**	**S2 2mel**	**S2 4mel**	**S2 5mel**
S2 2mel	0.546			
S2 4mel	0.413	0.870		
S2 5mel	0.461	0.852	0.831	
S2 6mel	0.390	0.694	0.668	0.696
Variable	**S3 1mel**	**S3 2mel**	**S3 4mel**	**S3 5mel**
S3 2mel	0.557			
S3 4mel	0.398	0.554		
S3 5mel	0.513	0.760	0.651	
S3 6mel	0.415	0.674	0.666	0.712

Table 3
Correlation between averaged timing profiles of conditions (averaged over repetitions) split by performer. The correlations are the same for scaled, normalised and raw eighth note IOI patterns.

The correlations between melody eighth note IOI's within conditions and between subjects were all significantly greater than 0 and generally significantly smaller than correlations of repeated performances ($p < 0.05$). In other words, the timing profiles of the melody of a single condition by different performers were related but showed clear differences as well. The correlations between performers (within conditions) were, on average, lower than the correlations between conditions and within performers (the correlation between performers is further discussed in section III.1.c and in figure 10). This means that in this study the timing patterns found are in general more typical for performers than they are for conditions[2].

III.1.a Ground pattern

The timing contour of the melody is different for the different musical settings of the melody; still, there is considerable consistency and similarity between the profiles of different conditions within subjects and even between subjects. To get a first general

[2] Such characteristics could be due to a persisting personal performance style (e.g. give and take rubato (S2) vs. gradual acceleration and deceleration of tempo (S3)) or it could be more a matter of structural interpretation (e.g. focus on melody (S1) vs. focus on multiple aspects (S2)).

impression of the way in which the performers time the melody we discuss the main characteristics of the grand average of all performances. Such a grand average highlights the aspects shared by all performances and diminishes the variable aspects. In this way the grand average can be seen as an indication of a "ground pattern" shared by the different performances

The grand average timing profile is shown in figure 8. There are a couple of aspects that characterise this timing pattern. First of all, the repeats of the first and second half have a very similar timing profile, with only the last measures of the second half being timed differently the first and second times through (this is because the phrase final lengthening at the end of the piece does not occur the first time through). Second, the large peaks at 17 and 44 coincide with a greatly lengthened ornamented eighth note of measure 6. The smaller peaks in 56 and 83 coincide with a lengthened ornamented eighth note in measure 10. Third, the first half and second half have different timing profiles. The first half speeds up towards the second beat of measure 3 (score-time 10 and 37 in figure 8) and slows down towards the end of the phrase in measure 9 (score-time 27 and 54 in figure 8), with the locally lengthened ornamented eighth notes in the middle. The second half has less clear accelerations of tempo. It does contain clearly lengthened notes, which occur more frequently compared to the first half. Phrase final lengthening occurs in the second half two times as much as in the first half, due to the sub-phrase ending at measure 13 that is clearly marked by a lengthening, as can be seen in the figure at score-time 66 and 93 (repeat).

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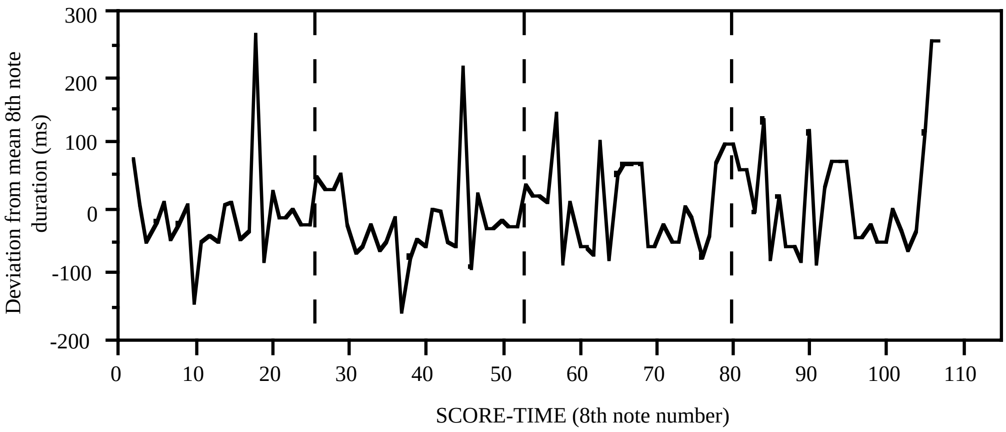

Figure 8

Grand average timing profile, calculated by averaging over all (scaled and normalised) timing profiles of the melody. The timing profile contains for each eighth note its deviation in milliseconds from the mean eighth note IOI. The dashed lines indicate phrase boundaries.

III.1.b Influence of contexts on timing contour

The grand average highlighted the common elements within the timing profile of the melodies. In this section, we examine the relative impact or influence of the contexts on the timing contour of the melody. The analysis is done in two ways. First, a factor analysis is used to obtain insight into the relatedness between the melodies of the different conditions. Second, partial correlations highlight the degree to which pairs of conditions are uniquely related with respect to the timing of the melody in the other conditions.

In the factor analysis, the data within one subject was satisfactorily explained by two orthogonal common factors (eigenvalue > 1), calculated by taking the rank order of the timing patterns of the melody as variables. The choice to use the rank orders was made to cancel out the possibility that one of the factors would represent the degree of (lack of) normal distribution. The disadvantage of this method is that the interpretation of the factors is less easily done on the ground of their own characteristics, but has to be reconstructed from the correlation measurements. The two latent factors explain on average 66.8% of the data. The largest factor contributes four to seven times as much to this explanation as does the second factor. This large factor can be seen as the basic form of a fundamental ground pattern that explains much of the timing variability. For S1 and S3 this ground pattern is most closely related to the melody of condition 6, while for S2 condition 2 correlates most highly with the main factor. The second factor is orthogonal to the first factor. The conditions that most highly correlate with this second factor (and correlate only to a minor degree with the main factor) are: for S1, the melodies of condition 4; for S2, the melodies of condition 6; and, for S3, the melodies of condition 2 (see figure 9).

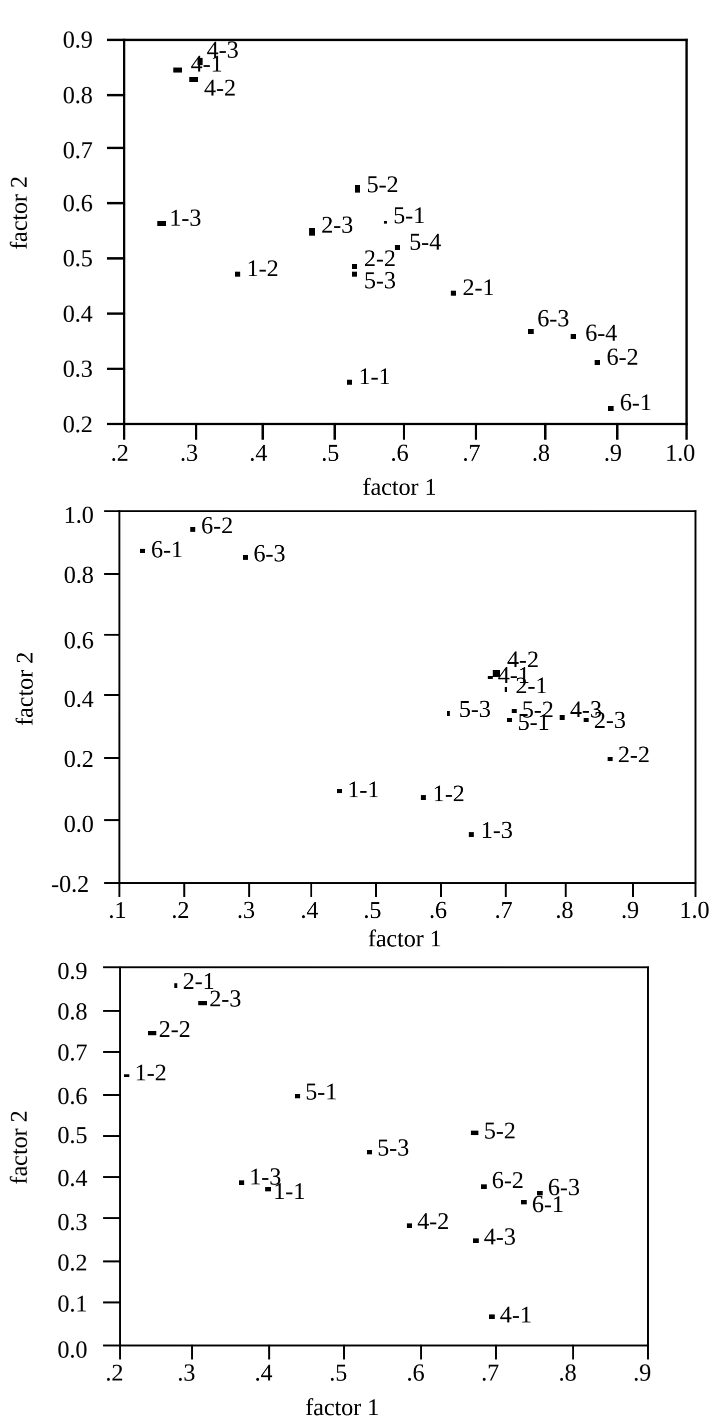

Figure 9

Loading of each condition on the two factors calculated in a two-way factor analysis. Variables are the (scaled and normalised) timing patterns of the melody of single performances. Number combination: indication of condition – indication of repetition

On the ground of these correlations some characteristics of the two factors were reconstructed. The main factor of S1 contains, in the first half of the piece, a clear periodic pattern of accelerations and decelerations. The second half, however, is better characterised by a high density of large local lengthenings and shortenings, such as the lengthening (and compensation of the lengthenings) of the ornamented eighth note and of the third beats of measures 12 and 15. The second factor that is needed to explain the performance of S1 primarily consists of a global, constant tempo, with small local decelerations. The second half of this factor has a greatly lessened density of timing changes, compared to the second half of the main factor.

The main factor of S2 consists of a global constant tempo with local lengthening of the ornamented eighth note and of the upbeats to measures 8, 9, 15 and 16. The second factor contains a global speeding up of the tempo. It also contains clearly pronounced acceleration-deceleration patterns. Lengthenings primarily occur in the first half, such as at the first beat of measure 3 and 5 and the upbeat to the repeat of the first half. In the second half accelerations occur towards the second beat of measure 15 and the end of measure 16, the middle of the last phrase.

The two factors that explain a considerable amount of the data of S3 are less easy to characterise and separate from each other than the factors used to explain the data of S1 and S2. The main difference between the factors of S3 is the point of direction to which accelerations and decelerations occur. In the main factor gradual accelerations occur within a phrase, while the tempo decelerates at the end of phrases quite suddenly and quickly. In the second factor, however, this is reversed, in that sudden accelerations are followed by gradual slowing of the tempo.

For each pianist a particular timing strategy becomes clear. For S1 condition 4 and condition 6 represent two opposed ways of timing the melody, while conditions 2 and 5 are timed in ways that are quite similar to each other as well to the other conditions (see figure 9, upper graph). For S2 conditions 2, 4 and 5 are all very similar to each other. S2 is very consistent over repetitions as well as over conditions, with only conditions 1 and 6 timed in a different way. Condition 6 correlates highly with the second factor explaining the similarity between the performances, but hardly relates to the main factor, which makes it clearly different from the other conditions (see figure 9, middle graph).

The data of S3 imply a strategy in which each condition gets its own individual timing characteristic. From the factor analysis, it becomes clear that for S3 each condition has its own characteristic profile, being both related and differentiated from the other conditions. Only 1mel does not have such a clear and distinct profile. For S3, the timing of 4, 5 and 6mel are most closely related to each other. Within these three conditions 5mel is most closely related to 2mel. It seems as if 6mel is a prototypical performance of the melody, which 4mel and 5mel approach. 2mel is different from the other conditions by its high correlation to factor 2 and low correlation to factor 1.

For all subjects, the performance of 1mel is least consistent and least characteristic of all performances, correlating only to a minor degree to both factors. It seems as if the melody without metrical and phrasing information provides limited or confusing information about the musical identity of the melody, which may account for its low "representative" status as a performance of the melody.

A different way of looking at the impact of contexts on the timing of the melody is by calculating, for each performer, the partial correlations between averaged timing profiles (averaged over repetitions) of the different conditions. In table 4 partial correlations between conditions are shown separately for each performer. Partial correlations show the remaining correlation between conditions when the features common to all conditions have been corrected for. In other words, the partial correlations give insight into the amount that certain conditions relate to each other more than average. The benefit of partial correlations beyond simple correlations is that the similarity between conditions is not due to agreement between all conditions, but rather is specific for the pair of conditions. This is of importance since all conditions consist of the same melody and thereby share perforce many similarities. For the decision between high and low partial correlation we take a partial correlation of 0.27 as a border, since below 0.27 the correlation would not be significantly greater than 0 ($p < 0.05$).

Variable	**S1 1mel**	**S1 2mel**	**S1 4mel**	**S1 5mel**
S1 2mel	0.531			
S1 4mel	0.103	0.390		
S1 5mel	-0.060	0.174	0.329	
S1 6mel	0.035	0.114	-0.064	0.656
Variable	**S2 1mel**	**S2 2mel**	**S2 4mel**	**S2 5mel**
S2 2mel	0.349			
S2 4mel	-0.163	0.547		

S2 5mel	0.037	0.371	0.314	
S2 6mel	0.038	0.152	0.101	0.231
Variable	**S3 1mel**	**S3 2mel**	**S3 4mel**	**S3 5mel**
S3 2mel	0.290			
S3 4mel	0.072	-0.009		
S3 5mel	0.128	0.451	0.270	
S3 6mel	-0.032	0.265	0.364	0.271

Table 4

Partial correlations between averaged timing profiles (averaged over repetitions) of four conditions, split per subject. The correlations are the same for scaled, normalised and raw eighth note IOI patterns.

From the partial correlations the influence of each musical setting of the melody seems to be as follows. Condition 1, the melody without bar-lines and other performance indications, shows very low partial correlations with all other conditions, with the exception of condition 2. This confirms that this condition is performed in an atypical way. However, it is worth noting that, for conditions 1 and 2, the correlations between melody with and without bar-lines are small, but the partial correlations are relatively large. This means that the common features between condition 1 and 2 are not very large, but they are very specific to these two conditions.

The addition of the counter-melody to the melody is interpreted differently by the different subjects. For S1 and S2 the effect of this combination is limited. They time the melody in combination with the counter-melody in much the same way as they timed the melody solo. This is not because the timing contour of the counter-melody solo and the melody solo are so much alike (they are quite different instead--the correlation between 2mel and 3counter-mel is, on average, 0.23). It is, rather, a result of what we take to be these performers' primary focus on the melody. For S3, however, the addition of the counter-melody changes the timing of the melody considerably. The correlation between the melody only and the melody with counter-melody is for S3 the lowest correlation between conditions, together with the correlation between the melody only and the melody without bar-lines (*r* = in both cases 0.55) (see table 3). Our intuition is that these low correlations are due to S3's greater sensitivity to the details and specifics of each musical context.

S2 and S3 time the melody with the block chords in a manner most like condition 2, the melody solo. For S2 this is not a surprise, as he does not change the timing of the melody much in conditions 2, 4 and 5 in any event. For S3, however, this is a bit more surprising. S3 times the melody in condition 5 much more in the way he timed the melody solo than was the case with the melody and counter-melody combined. For S3 the addition of the harmony of the block chords does not seem to make a large difference with respect to the melody solo.

For S1 it is interesting to see that condition 5 is, of all conditions, timed most like condition 6. In other words, for this subject the melody with block chords in condition 5 approximates the final version of the melody to a large extent. It seems as if the chords and the melody in condition 6 have a relative large impact on the timing contour for S1, in contrast to the melody in relation to the counter-melody which is less well represented in condition 6.

S2 performs condition 6 in a way that is quite different from the other conditions. Apparently his conception and performance of the melody changes considerably with the addition of the full context in the Theme. For S3 the melody in condition 6 correlates almost equally well with the melodies in conditions 2, 4 and 5. The partial correlations, however, show a larger similarity between the timing of the melody in condition 4 and 6 than between condition 2, 5 and 6. This implies that the melody in condition 6 approaches the melody in condition 4, which suggests that S3 takes the counter-melody in condition 6 into account in the timing of the melody. A regression analysis substantiates this suggestion by indicating that the timing profile of the counter-melody in condition 4 is able to explain 20% of the timing variation of 6mel and 30% of the timing variation of the counter-melody in condition 6 (6counter-mel).

III.1.c Similarity between performers

From the outset of this study we were interested in the way in which pieces offer different possibilities for performing the piece with tempo rubato. The idea was that certain pieces are interpreted in a highly consistent way while other pieces will tend to give rise to multiple timing patterns. In this study we found that the agreement in timing profile between the performers is not equally great for the different conditions. The correlations between averaged timing profiles (averaged over repetitions) of different performers is for the melody without bar-lines and (partly) for the melody alone significantly higher ($p < 0.05$) than for the Theme (see figure 10).

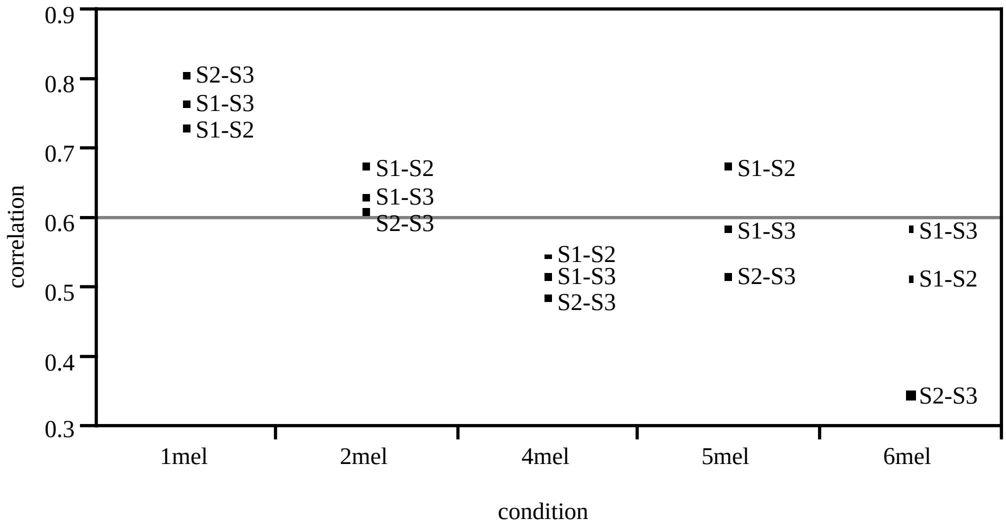

Figure 10a

Correlation between averaged timing patterns (averaged over repetitions) of performers split by condition. All pairs of correlations in condition 1 are significantly greater than the pairs of correlations of conditions 4 and 6 ($p < 0.05$). The mean correlation between performers in condition 1 is also significantly greater than the mean correlation between performers of condition 5 ($p < 0.05$). The correlation between the timing profiles of S2 and S3 of 2mel is significantly greater than the correlation of 6mel ($p < 0.05$). The correlations are the same for scaled, normalised and raw eighth note IOI patterns.

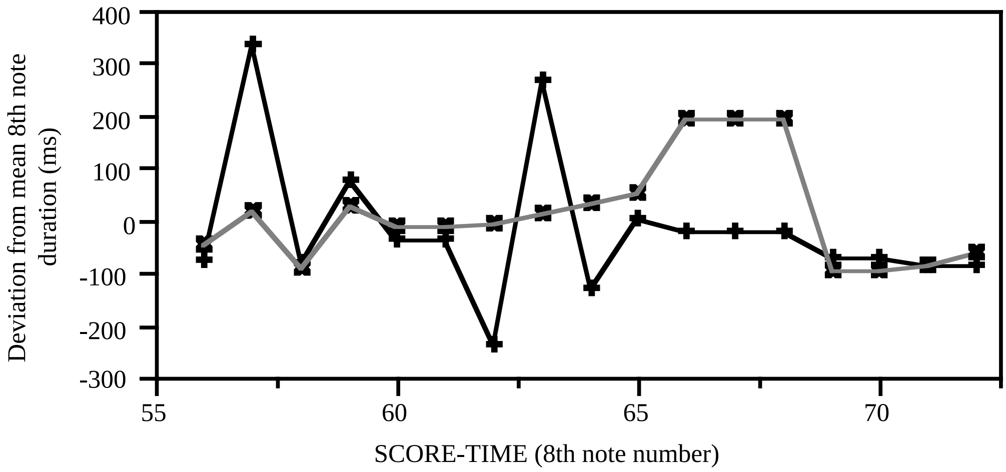

Figure 10b

Example of the (scaled and normalised) timing profiles of the melody in condition 2 and condition 6 performed by S2 and S3. Score-time 56-72 refers to the upbeat of measure 10 to the first beat of measure

15. The differences between the timing profiles of S2 and S3 are in condition 6 (below) clearly greater than in condition 2 (above).

The high correlation between the timing profiles of the different performers in condition 1 seems due to the relative large lengthening of the ornamented eighth note in contrast to the generally small timing variations. For the descending trend of the correlations over conditions 2, 5, 4, and 6, however, we would like to posit an interpretation that needs further testing in future research. In figure 11 the correlation between subjects (taken as a measure of similarity between performers) is plotted for conditions with increasing diversity/complexity of musical structure. We see that the similarity between performers decreases (the variability between performers increases) with increasing diversity of musical structure. In this graph the least "diverse" musical structure is the melody alone, which is timed in a quite uniform way (mean correlation between the performers = 0.64). The second-least diverse structure is the melody with block chords (having one melodic line and harmony) which is still timed with some substantial agreement. The second most diverse structure is the melody with the counter-melody (having two melodic lines and harmony). For this condition the correlations are all a bit lower (r = 0.52). The most diverse structure is the full Theme (having two to three melodic lines, harmony, and arpeggio chords); the melody within this complete Theme is timed with least agreement (mean correlation between the performers = 0.48).

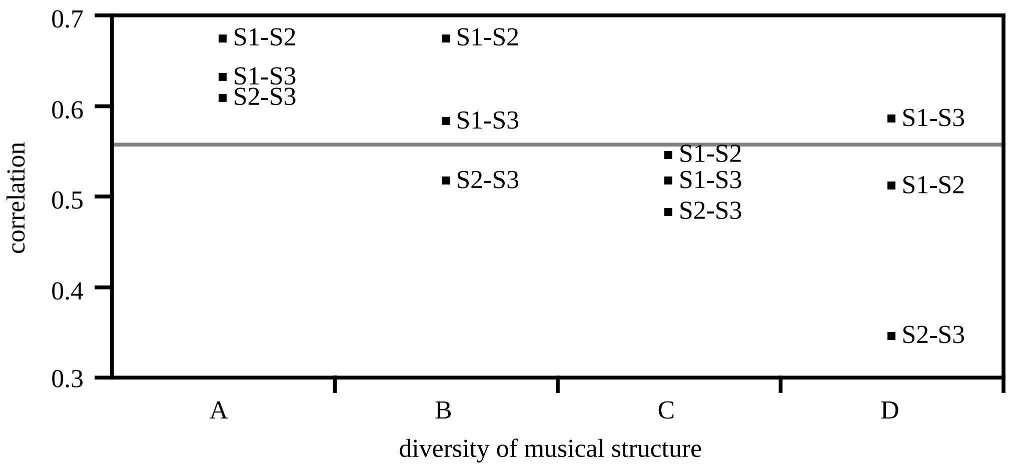

Figure 11

Correlation between averaged timing patterns (averaged over repetitions) of performers plotted by conditions with increasingly divers musical structure. A = 2mel, B = 5mel, C = 4mel, D = 6mel. The correlations are the same for scaled, normalised and raw eighth note IOI patterns.

A reason for the similarity between performers' timing of the conditions could be an agreement in interpretation caused by a common performing practice or by limited interpretative possibilities of the music. A reason for the decrease of similarity between the timing profiles of the different subjects could be that, when there is more musical diversity, more choices and interpretations have to be made by the pianists, which they make in increasingly different ways. In this view a complex musical structure provides several interpretative possibilities, while a simple and plain musical piece provides less room for alternatives. Supplemental support for this hypothesis is found in the changing timing profile of the melody in different conditions. Among conditions 4, 5 and 6, the Theme (condition 6) differs the most from condition 2, which is probably due to the great number of new elements in the musical context of the melody within the Theme. In other words, the timing of the melody within performers changes the most with diversity of musical structure, as was also found between performers, within conditions.

The decrease of similarity between performers with diversity of musical structure is, however, not entirely self-evident. An arguable and contrasting effect that might be found would be an increase of similarity between performers with increasing musical complexity, because of constraints or direction provided by the structure. A melody on its own provides limited cues for its interpretation while a melody with contexts in which harmony, meter, and grouping are more strongly defined provides many more cues to be heeded. With increasing complexity of the musical context, these effects could become more pronounced. For example, a Bach four-voice fugue is likely to be played in a rather strict manner with respect to timing variations, due to the complex way in which the voices interact with one another. In that case it seems unlikely that increasing complexity of structure would yield greater potential for flexibility of timing.

III.1.d Diversity between conditions

Having introduced a hypothetical ground pattern, it would be interesting to know what, exactly, is timed consistently over different conditions and what changes. Although a detailed discussion of this falls beyond the scope of this article, we do want to point out some of the common features and some of the differences. In general what we found is in substantial agreement with the explanations of expressive timing variations reported in the literature (cf. “Palmer (1996a)”, “Sloboda (1983)”, and “Sundberg et al. (1983, 1991)”); for example, all performers generally ended the piece with a phrase final lengthening. Consistent patterns were some rhythmic and metrical figures, such as lengthened upbeats (also found by “Desain & Honing (1994)”), shortened second beats (see composers pulse in triple meter “Clynes (1983)” “Repp 1989”) and a highly prolonged ornamented note.

Differences between conditions or between repetitions were often due to local changes in stress patterns at ambiguous places. For example, S2 timed the first few measures of condition 1 differently in each repetition (see figure 12). In repetition 2 of 1mel, S2 clearly lengthened the high notes in the melody and plays first beats relatively short. In 2mel, however, he instead lengthened the first beat of the second measure and favours metrical stress, indicated by bar-lines, over the stress of high notes in the melodic contour (possibly effecting a shift of downbeat by one eighth note).

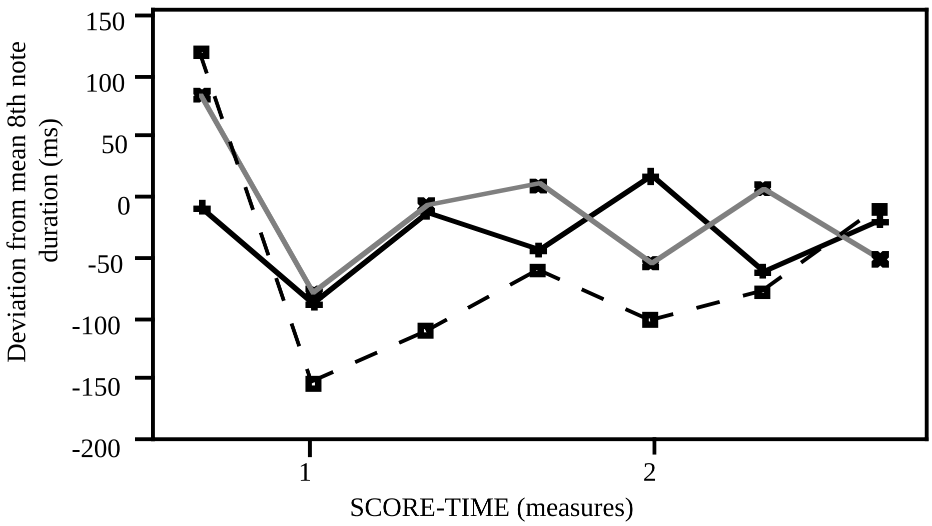

Figure 12

(Scaled and normalised) timing profile of the three repetitions of the first two measures of the melody without bar-lines performed by S2. From the second beat of the first measure on no clear timing pattern exists.

Globally consistent changes were minor. For S3, condition 5 shows a major change in timing in relation to other conditions in that the first beat of each measure is, on average, lengthened more than other beats in the measure. This regular pattern does not occur in the other conditions, and we interpret the lengthening as a result of the block chords occurring at the first beat of each measure in this condition. S2 treated condition 5 in a special way by varying the “chord spread”--the length of time between the onset of the first note in the chord and the last note in the same chord--expressively. In this condition, S2 performs some chords nearly simultaneously, while he breaks others noticeably. For an impression of the asynchrony in condition 5 for S2 see figure 13.

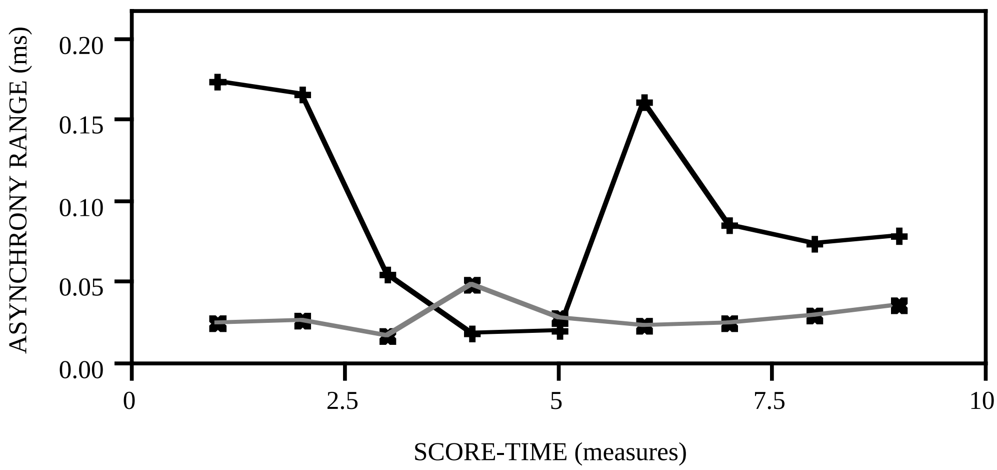

Figure 13

Example of S2 treating the asynchrony between voices as an expressive device in the condition of the melody with block chords. The asynchrony between voices is calculated by subtracting onset times of the first from the last note of a chord. In this graph only the first 9 measures are given.

Not all of our findings were in keeping with the implications of previous research. One finding that is not in agreement with previous research on this topic is the tendency of one subject to sometimes lengthen the notes in the middle of the phrase and to speed up towards the end of the phrase. This was the case for S2, who, in condition 5, lengthened either the third beat of measure 3, or the first or even second beat of measure

4, where after he speeded up towards the down beat of measure 5. In other words, he lengthens the notes in the *middle* of the phrase and speeds up towards the *start* of the new phrase (see figure 14), the opposite of the tempo curve given by the tendency toward phrase final lengthening.

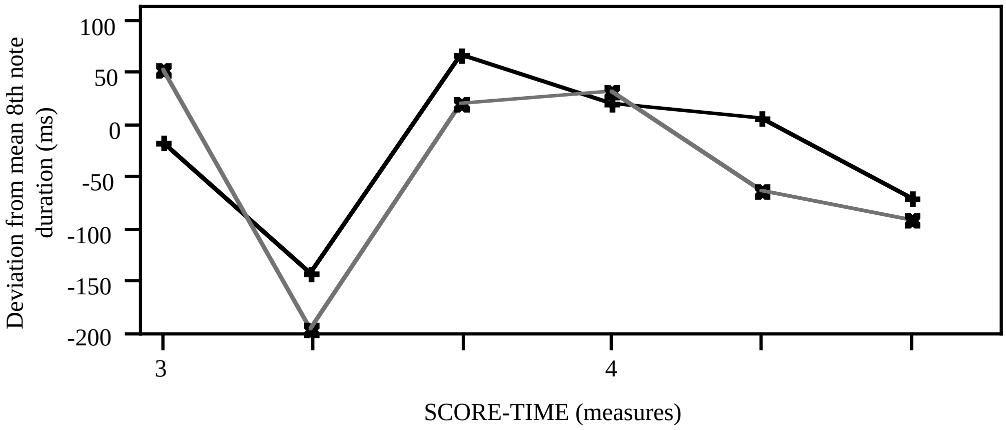

Figure 14
(Scaled and normalised) timing profile of measures 3 and 4 by S2. S2 speeds up towards the end of the sub-phrase in measure 5. The short note at the second beat of measure 3 consists of two sixteenth notes that are played very fast by all subjects, consistent over all conditions.

Another inconsistency with the literature is that the decelerations at the end of musical groups (phrases) are not the largest lengthenings of notes that occur. Instead, the ornamented eighth notes in measures 6, 10 and 12 are generally lengthened more than the notes at the end of a phrase; only the final phrase lengthening, at the end of the piece, has the degree of the lengthening of the ornamented eighth note (see figure 15). Still, the effect of the phrase final lengthening is greater than the effect of the ornament lengthening, since the lengthening of the ornamented eighth note is compensated by a fast preceding eighth note. The phrase final lengthening is, on the contrary, approached by a gradual slowing down of the tempo (see also figure 15). The lengthening of the ornament has therefor less impact on the duration of higher level units (e.g. a two-measure unit) than the phrase final lengthening has.

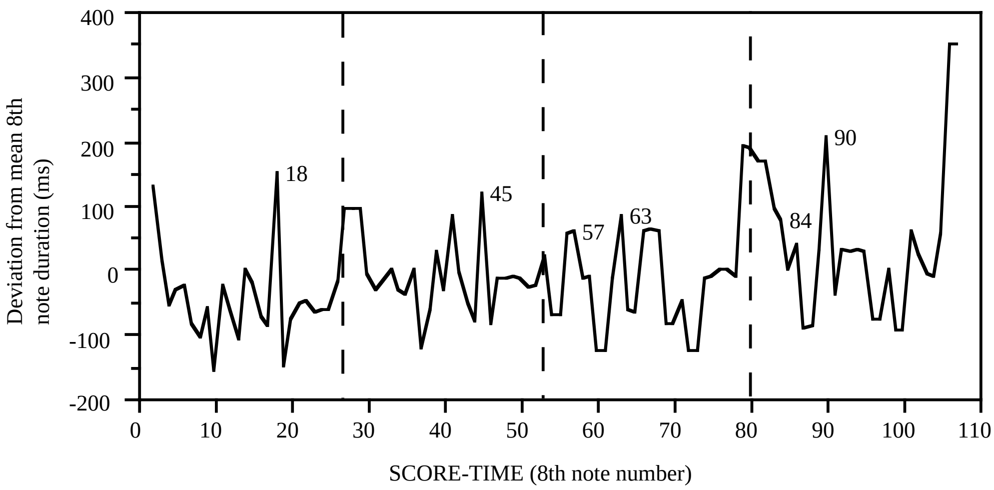

Figure 15

(Scaled and normalised) timing profile of one repetition by S1 of 2mel, rep 3. The phrase final lengthenings are not the greatest decelerations; instead the lengthening of the ornamented eighth note is often larger. The numbers indicate an ornamented eighth note in the score, the dashed lines mark phrase boundaries. Only the phrase final lengthening at the end of the piece is larger.

III.1.e Explanation of the changing timing profile of the melody; different voices, one timing profile

When we take the performance of the melody solo in condition 2 as point of reference, we notice that the timing contour of the melody changes when it is performed in different musical settings. The reason for this changing timing contour seems twofold:

1) Different voices are timed in a uniform way.

2) In the common timing pattern, different musical characteristics are highlighted, related to

- each voice, and to
- characteristics of the music due to the combination of the voices (such as harmony).

In other words, the timing contour of the melody does not remain the same when other voices are added, because supplemental characteristics of the other voices are taken into account by the pianist when timing the melody.

With reference to 1) the fourth condition provides our most provocative evidence for the statement. In this condition the asynchrony between the two voices is small (it lies between 0 and 55 ms, averaging 17 ms), which means that both voices are timed practically simultaneously (for a comparison see the chord spread S2 uses in condition 5, figure 13, which in average exceeds 50 ms). Further, the timing patterns of the two voices correlate highly (average correlation between the counter-melody and melody line of one repetition = 0.81), which suggests that the voices share a common timing pattern (see also figure 16). In fact, a correlation between the voices of 0.81 is as high as the correlation between melodies of repeated performances within a single condition. It is, further, much higher than the correlation between 2mel and 3counter-mel for example, which is in average 0.28 (0.33 for S2 and 0.22 for S3). We see this as an indication that the different voices of condition 4 are timed in a uniform way. (Remember: the analysis of condition 4 is only based on S2 and S3, because of missing notes in the counter-melody of S1.)

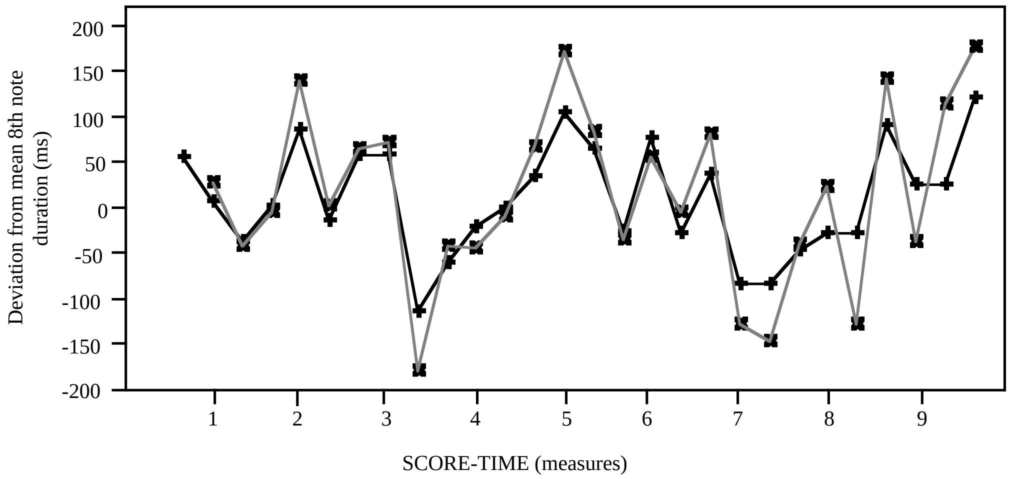

Figure 16

(Scaled and normalised) timing profile of the melody and counter-melody in measures 1-9 of condition 4 performed by S3. The timing profiles correlate highly.

With respect to 2) The timing patterns of condition 4 also provide insight into the relationship between the timing characteristics of the melodic lines alone and of the lines together when they are compared with the timing patterns of condition 2 and 3 provide. The timing patterns of condition 4 correlate significantly ($p < 0.05$) with both the melody solo and the counter-melody solo timing patterns (average correlation of condition 4 with

2mel = 0.67 and with 3counter-mel = 0.36). This means that aspects of both the melody and the counter-melody solo are present in condition 4.

A multiple regression analysis shows that the average timing patterns (averaged over repeats) of condition 4 can be explained fairly well on the ground of averaged timing patterns of condition 2 and 3. For S2 82.6% of 4mel and 56.8% of 4counter-mel is explained by 2mel and 3ten. For S3 the numbers are 36.8% for 4mel and 40.8% for 4counter-mel (for more detail see table 5). The significant contribution of both 2mel and 3counter-mel to the explanation of 4mel and 4counter-mel confirms that aspects of both the melody and the counter-melody solo are present in condition 4[3].

Performer	**Explained performance**	**by**	**Proportion of variance explained***
S2	**4mel**	**2mel**	0.76
		3ten	0.28
		2mel & 3ten	0.83
	4ten	**2mel**	0.56
		3ten	0.11
		2mel & 3ten	0.57**
S3	**4mel**	**2mel**	0.31
		3ten	0.13
		2mel & 3ten	0.37
	4ten	**2mel**	0.27
		3ten	0.12
		2mel & 3ten	0.41

* All contributions to the explanation of the explained performance are significant ($p < 0.05$) except **.
* * The contribution of 3ten to the explanation of 4ten is not significant, 2mel does significantly contribute to the explanation of 4ten.

Table 5
Regression analysis between averaged timing profiles (averaged over repetitions) of 2mel, 3ten, 4mel and 4ten. The (scaled and normalised) timing patterns of condition 4 are explained on the ground of 2mel and 3ten separate and of 2mel and 3ten together.

Although this explanation covers the data fairly well, the timing patterns of condition 4 cannot be fully explained by the linear combination of the melody solo and counter-melody solo. The unexplained part, which is quite large for S3, suggests that the combination of the counter-melody and melody lines in condition 4 produces a case of

[3] Note: For S2 the contribution of the counter-melody solo to the explanation of condition 4 is only significant for 4mel and not for 4ten.

the whole being more than the sum of the parts. Supplemental musical characteristics are introduced by this combination of voices: for example, harmonic intervals that are explicit as well as implied, as well as a new composite rhythmic texture and an interweaving of melodic goals between the two voices.

For S2 the contribution of 2mel and 3counter-mel to the explanation of condition 4 is asymmetrical. S2 seems to have the melody as his major focus in two ways: 1) The performance of both the melody and the counter-melody in condition 4 are very well explained by 2mel and to a lesser degree by 3ten, and 2) 2mel and 3counter-mel explain more of the performance of the melody in condition 4 than they do of the performance of the counter-melody in this condition. We interpret this as an indication of the melody in condition 4 carrying more *intentional* variation than the counter-melody in this condition. That is to say, the melody line continues to be the focus of intentional variation on the part of the player, while the counter-melody is less carefully modulated for expressive purposes. Rather than having a truly independent life of its own, the counter-melody seems to be modulated by the changes in the melody-- the melody seems to be leading the expressive variations of the counter-melody.

III.1.f Tempo and motor factors

The influence of some other factors, other than musical structure, on the timing of the melody were not cancelled out in this study. For example, the full Theme (condition 6) was harder to perform than the melody or counter-melody solo. This resulted mainly in a change in mean tempo, with the Theme being performed on average more slowly than the other conditions. The timing profile itself would be affected largely in the area of difficult chords vs. easy chords to perform. That is to say, difficult chords might need extra preparation, which would probably lead to a lengthening of the previous note. We think, however, that the influence of this preparation is limited. This is suggested by the slower mean tempo (probably taken by the performers to allow for increased difficulty of the material) and by the high consistency over repetitions of the timing profiles for the

Theme (condition 6) and melody with block-chords (condition 5). The consistency over repetitions of the last conditions was as high as (or even higher than) the consistency within other conditions. This means that the timing variations found are in large measure intentional. From hearing the performers at work we are confident that S2 and S3 are skilled enough to perform the Theme in the way they intended. For S1, however, we are not entirely confident about this. The hand size of S1 could have been a constraining factor in his performance of the Theme[4].

The influence of tempo as a factor altering the timing contour was not cancelled out either. We tried to limit its influence by indicating the ideal average tempo to the subjects. They were however, not able to restrict themselves to the indicated tempo and changed the tempo in accordance with the various conditions (see table 1). It is very well possible that some of the differences in timing pattern between conditions are partially a result of tempo differences.

The musical context of the melody, however, is the primary source of the differences in timing patterns, since it is the main cause of the motor and tempo differences and since the differences in the timing patterns between conditions is demonstrated to be the result of new aspects in the context for several cases.

III.2 Extent of tempo rubato

In this section of the study, the extent of tempo rubato and its relationship to musical context will be considered. In order to be able to compare the extent of tempo rubato of performances in different tempi, we scaled all performances to one tempo (the slowest tempo = 54 eighth notes per minute). We divided the IOI's of a single performance by its mean eighth note IOI and multiplied this by the new, standard mean eighth note IOI (which is 1132 ms). We did this to create a uniform scale for tempo variations in which rubato extents within different tempi can be compared to each other.

[4] Indeed, S1 reported that he encountered difficulties with the performance of the wide chords of the Theme.

All observations about the rubato extent are made relative, not absolute. When no such scaling would be made, the differences in rubato extent would be considerably larger than reported below, due to global tempo differences. By scaling all performances to the same average tempo, the differences in the extent of rubato are underestimated. We can therefore be sure that significant differences in the extent of tempo rubato between performances are indeed significant. In other words, we wanted to be sure that an increase in variability is an increase in relative variability, that is, relative to the mean tempo. For example, a small lengthening or shortening of notes in a slow tempo is (when taken in absolute terms) relatively large in a fast tempo.

III.2.a Performer characteristics

When the performances are scaled it becomes clear that the three subjects use approximately the same amount of tempo rubato. Only S3 uses tempo changes that are a bit smaller than those produced by the other subjects. On average the standard deviation of the eighth note IOI is 108 ms, which is 9.54% of the mean eighth note duration (average eighth note duration of the scaled performances = 1132 ms).

This similarity in extent of timing variability was a surprising result for us. The performances did not sound like as if they had a similar extent of timing variations. Apparently, more aspects of the tempo changes than the extent of tempo rubato alone influence the impression of the amount of tempo rubato used by performers. The kind of tempo rubato used could be the significant factor, or perhaps the density of tempo changes could play a role. S2 and S3 showed very different kind of tempo rubato. While S3 made global and gradual tempo changes, the timing characteristics of the performances of S2 are better described as give and take and are more local.

III.2.b Conditions

All subjects change the rubato extent with respect to the performed music. For S1 the eighth note IOI variance is in 2mel and 4mel rather small, in 1mel it is moderately large and for 5mel and 6mel it is fairly large (see figure 17). Significant differences between the mean standard deviation per condition are: 1) 6mel is timed with greater tempo variance (duration variance) than all melodies in other conditions ($p < 0.01$), and 2) 5mel and 1mel are timed with greater tempo variance (duration variance) than 2mel and 4mel ($p < 0.05$)[5].

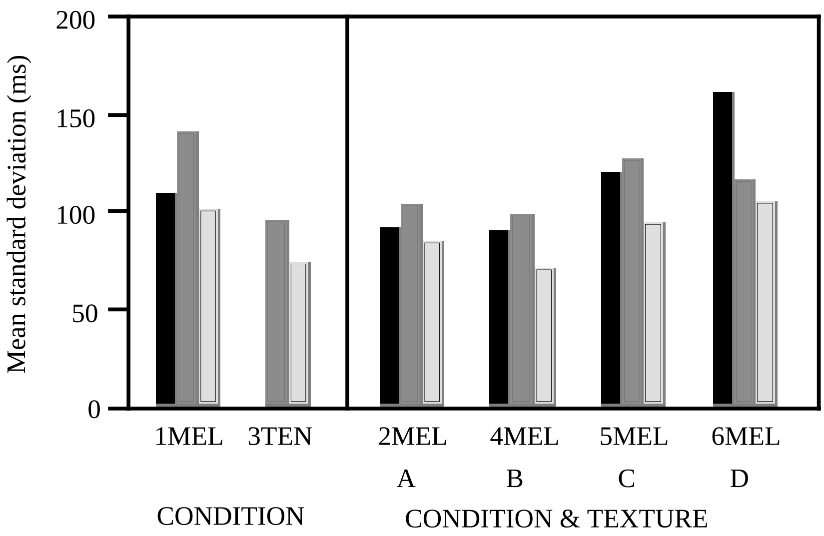

Figure 17
Average standard deviations in ms (averaged over repetitions) of the scaled timing profiles split by performer and conditions. The letters A-D indicate conditions with increasingly rich musical texture. A = 2mel, B = 4mel, C = 5mel, D = 6mel

For S2 the variance of eighth note IOI of 1mel is greater than in the other conditions (except 5mel). This tempo variance is mainly due to a very large lengthening of the ornamented eighth note. The tempo variance of 2mel, 3ten and 4mel are the smallest and the variance of 5mel and 6mel are in between (see figure 17). The tempo

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[5] Differences between std deviation measurements of timing patterns were calculated by the dividing the largest variance (s square) by the smallest variance which gave the F distribution. The *p* value can than be found by using the degrees of freedom of the nominator and denominator (see also "Hays & Winkler (1971)").

variance of 1mel is significantly greater than the tempo variance of 2mel, 3ten, 4mel and 6mel ($p < 0.05$). The tempo variance of 5mel is significantly greater than of 2mel, 3ten and 4mel ($p < 0.025$). The tempo variance of 6mel is greater than of 3ten ($p < 0.05$).
The large rubato extent of condition 5 is probably a result of the asynchrony with which S2 performs the block-chords. In condition 5, S2 uses asynchrony as an expressive device; he sometimes plays the chords broken and sometimes simultaneously.

S3 uses the least tempo variation for 3counter-mel and 4mel. For 1mel, 2mel and 5mel it becomes increasingly greater and for 6mel it is the highest (see figure 17). S3 times the melody in condition 6, 1, 5 and 2 with significantly larger tempo variation than the melody in condition 4. The timing variance of the melody in condition 1, 5 and 6 are greater than the timing variability of 3ten. In other words, the timing variation of conditions 3 and 4 are significantly smaller than the timing variations in all other conditions.

III.2.c Texture

When only the melody of condition 2, 4, 5 and 6 are considered, a general trend occurs: the extent of rubato appears to increase with richness of musical texture. In figure 17 this relation is depicted. The extent of tempo rubato is plotted by conditions with increasingly rich texture. The mean extent of rubato of a performance is represented by the standard deviation of the eighth note IOI's. The texture is indicated by numbers (1 to 4) which represent conditions with increasingly rich texture. Condition 2 (texture 1) has a plain texture (one voice), while condition 4 (texture 2) has the next plain texture (2 voices). Condition 5 (texture 3) has the next-richest texture (three to four voices), while condition 6 (texture 4) has the richest texture of all (four to five voices).

It is interesting to see that the diversity between performers and the amount of tempo rubato used do not behave in the same way. While in condition 4 the performers differ quite a lot in their timing of the melody, they all perform this condition with small tempo rubato; In other words the melody with counter-melody condition provides an expressively differentiated or varied source, but it does not lend itself for large tempo rubato. On the other hand all performers time condition 5 with deep tempo rubato which, however, does not mean that the diversity in tempo rubato patterns increases in this condition.

III.2.d Confounding factors

The design of this study did account for enough degrees of richness of sound to be confident about these factors influencing the extent of tempo rubato. Nevertheless, in musical situations of this complexity, one should be aware of possible conflicting factors that were not accounted for in this study. A possible influence on the extent of tempo rubato was, for example, the constraining influence of the counter-melody on the melody in the performances by S3. The musical texture is richer in condition 4 than in condition 2 (melody alone). Still, S3 performed condition 4 with a smaller extent of tempo rubato than condition 2, which is probably due to the counter-melody being preferably timed with small tempo rubato (see figure 17).

The rich texture in condition 5 and 6 is a complex factor containing influences of various kinds. Condition 5 and 6 are not only characterised by a richer sound, but also by broken chords, wide chords and dense musical passages which are motorically demanding (for example the ornamented eighth note in measure 6 and the sixteenth notes in measures 7 and 8). These local characteristics are related to the richer musical texture, but have different origins. They cause local lengthenings, which increase the globally measured extent of tempo rubato. Rather than condemn these local delays we think they probably belong to the compositional intent of Brahms, who was a pianist himself and who should have been aware by the time delay caused by arpeggio chords and by the separation of bass and chord notes by more than an octave (see figure 6).

V Conclusion

Three pianists performed a melody in five different settings. These settings theoretically provide different expressive possibilities. These possibilities were translated by the pianists into differences in timing contour, extent of tempo rubato and use of expressive devices (for example, asynchrony was used expressively in the conditions with chords). The pianists were generally consistent in their timing of the melody within a single condition.

Differences in timing contour between conditions consisted of the lengthening of beats to which chords are added, shifts in points towards which is accelerated or decelerated, shifts in locally lengthened (and thereby accented) beats. The condition in which the melody was given without bar-lines, rhythmic beams and phrase indications was timed in the least idiomatic manner. The impact of the contexts on the timing of the melody depended on the context and the performer. One subject considerably changed the timing pattern only with the addition of the full context. Another subject was especially sensitive to the presence of a counter-melody. Explanations of the changes in timing contour were based on the ground of two observations: 1) Different voices are timed in a uniform way. 2) In the common timing pattern, musical aspects are highlighted that relate to structural aspects of both the individual voices and the combination of voices.

The extent of tempo rubato appeared to be modulated in a much more systematic way than could be expected from the lack of interest into this aspect of tempo rubato in previous studies. The extent of tempo rubato was found to increase with richness of musical texture. The melody, when played alone and in the context of the counter-melody, was timed very much in tempo, while the fuller textures of condition 5 and 6 resulted in deep tempo rubato patterns. Locally, changes found consisted of an increasing use of accelerations and periodic tempo variations in later conditions with richer musical structure. Both the amount of the final retard and the amount of lengthening of the ornamented eighth note changed in accordance with the globally found extent of tempo rubato.

In addition to the findings mentioned above, the study has shown to be fruitful in a number of ways. First, a relationship between diversity of performances and musical structure has been found. The diversity of performances increased with the number of explicit musical dimensions in the score (such as melodic lines and chords). This is a relationship not often reported in the literature, and seems to be related to the complexity of musical structure, or at least to the presence of multiple cues in the musical texture. Second, a beginning has been made in investigating the scope of musical elements that pianists take into account when performing structurally diverse music. This scope appeared to be different for different pianists. One subject focussed strongly on one aspect of the music (the melody), while another took multiple aspects of the music into account. The degree of sensitivity to multiple structural descriptions is possibly related to musical experience. This hypothesis has also been stated by “Clarke (1988)”, but needs further investigation. Last, but not least, this study has contributed to the discussion of ‘the tempo curve considered harmful’ “Desain & Honing (1993)”. Timing patterns appear to depend heavily on the musical events or musical structure in which they are originally produced, meaning that they have limited generality over different pieces.

We conclude that pianists take different parameters of the music into account when deciding on the timing of the melody of a piece. This is shown by the changing interpretation of the melody in the different conditions, but also by the contribution of both the melody solo and the counter-melody solo to the melody and counter-melody in combination.

We are cautious, however, about generalising the results of this study. Its generality is limited by the scope of the study, which included only different versions of one piece, and only diversity of performances between three pianists. In this set-up, the influence of each performer is quite large, which means for example that if one pianist times a certain melody very different, it lowers the correlations considerably.

Further investigation is needed in which the musical factors influencing the diversity and extent of tempo rubato patterns are separated and tested. The scope of the study should be broadened to include other expressive devices such as dynamics, articulation, chord spread. The purpose of such a study is to further clarify the constraints on or freedom of performing the piece expressively.

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Appendix

POCO

POCO is a workbench for analysing, modifying and generating expression in music, to be used in a research context. POCO contains a consistent and flexible representation of musical objects and structure. The integration of existing models of expression makes it possible to compare and combine models using the same performance and score data. New tools are developed for specific “micro surgery” on expression. A lot of attention is given to the openness, integration, and extendibility of the system “Honing (1990)”.