An empirical study of intonation in performances of J.S. Bach's Sarabandes: temperament, 'melodic charge' and 'melodic intonation'

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Abstract

As part of a wider research aimed in exploring ideologies and prevalent conventions in the 'early music movement', intonation analysis was carried out through comparative study of a selection of recorded performances of J.S.Bach's Sarabandes for Flute and Violoncello solo. The recordings, made by prominent 'historically informed' and 'mainstream' performers of different periods, were analyzed for their compliance to the mean temperament tuning offered by various scholars as representing the historical practice. Intonation discrepancies of up to 39% were found in the interval sizes made by both groups of performers. Differences between both groups have been traced in the manner of execution of chromatic intervals only. Following analysis, an examination of data was made in light of Sundberg, Frydén and Friberg's rule system for musical expression. Its aim was to investigate the effect of notes of significant 'melodic charge' and 'melodic intonation' values on intonation tendencies. No correspondence was found between both rules and the measured intonation deviations. Results point to the limited influence of theory over practice where intonation of non-fixed pitch instruments is concerned, and show that intonation should not be regarded as a distinctive element of practice as regards to 'historically informed' performances. Results also point to the limited effect of a note's 'melodic charge' and 'melodic intonation' values on its performed intonation, and suggest a possible discrepancy between analysis-by-synthesis and analysis-by-measurements strategies.

Background

Early music movement

The term ‘early music movement’ (also ‘authentic’ or 'historically informed') is commonly used to describe the large group of musicians who strive for performing early music repertoire in the ‘authentic’ way in which it has historically been written and performed. This aim is to be achieved through various means, such as performance on historically oriented instruments, acquaintance with historical treatises dealing with performance practice or the reconstruction of a multitude of performance parameters which were lost or else went through extreme transformation throughout the years. The term ‘mainstream performers' is commonly used to describe the large group of performers using “modern” instruments that do not affiliate themselves to the early music movements’ agenda.

While challenging performance practice conventions common among their ‘mainstream’ colleagues, prominent early music activists have held the viewpoint by which thorough, direct acquaintance with past traditions was necessary for the proper performance of historical repertoire. Rejection of the model of historical progress coincided with the preference for ‘historically oriented’ instruments and with the view in which the composer serves as the highest authority over the performer (Dart, 1961, Restout & Hawkins, 1969, Dolmetsch, 1969, Goble, 1977, Donington, 1982). Putting period instruments' inherent idiomatic devices and sonic elements into the forefront, the use of original pitch and temperament was regarded essential for the proper deliverance of composers' intentions (Dart, 1954, Donington, 1963, Frotscher, 1981).

However, such traditional, 'positivistic' attitudes traced in the writings of pioneers active since the beginning of the last century have been increasingly challenged by performers and scholars from within the movement itself. Invalidation of traditional research as a tool for the reconstruction of composers' intentions was presented hand in hand with justification for pluralistic attitudes to interpretation. The performer's individual utterance was presented as equal in importance to that of the composer, while the use of 'modern' instruments in early music repertoire has been utterly legitimized (Morrow, 1978, Neumann, 1978, 1982, Dreyfus, 1983, Kerman, 1985, Crutchfield, 1988, Tomlinson, 1988, Taruskin, 1995). Critical attitudes were additionally presented in regards to the use of meantone temperament, considered more relevant for keyboardists than for players of non-fixed pitch instruments, unpractical for orchestra playing, unsuited for the transfer of the Baroque 'affect' to modern audience, or reflecting hidden nostalgia for pre-modern social orders (Donington, 1973, Harnoncourt, 1988, Neumann, 1989, Butt, 2002).

The existence of a wide spectrum of ideological attitudes could best explain the apparent lack of uniform standards of practice, as suggested by some recent studies on the issue. Traced in recordings of 'historically informed' performers of different periods, performance elements such as tempo, dynamics, rhythm or ornamentation have been found featured in various styles and manners (Fabian, 1997, 2003, Ornoy, 2006).

However, in a recent study aimed in exploring ideologies and ruling conventions in the early music movement, it has been found that contrary to critical positions, currently active early music performers show a clear tendency towards traditional, 'positivistic' standpoints in regards to several aspects of performance. In a survey conducted among a large group of professional 'historically informed' performers, the majority of

players have shown full, sweeping support for reading historical treatises, for choosing historically oriented elements of musical expression in the process of performing early music (such as sound production in accordance with the original instrument constraints, relevant types of vibrato, means of articulation, etc.), and for the use of intonation and temperament which they regarded as relevant to the historical period performed (Ornoy, 2002).

Intonation analysis (study 1)

Faced with such declarations, it seemed interesting to observe to what extent they are carried out. Hence, intonation analysis was conducted through comparative study of a selection of recorded performances of Baroque repertoire, made by prominent 'historically informed' performers of different periods (study 1). Examined for the manner of execution of melodic intervals, analysis was based on comparison between the suggested mean temperament tuning representing the historical practice, as offered by various models, and the interval sizes carried out in practice.

'Historically oriented' performers were additionally compared to their 'mainstream' equivalents. This was made in order to observe differences as well as similarities between both groups in regard to intonation.

Results have shown intonation deviations found to a large extent among both groups of performers (Short abstract of this study results has been most recently published. See Ornoy, 2006).

Sundberg et al. rule-system of musical expression

Deviations from the original musical score have led to several projects aimed in generating cognitive models of interpretation. An important project is the one led by Sundberg, Frydén, Friberg et al., who have attempted to formulate an overall rule-system for musical expression by using an analysis-by-synthesis strategy (by which a musical expert evaluates the performance of a computerized system).

The primary intention of the rule-system generators was to make explicit the intuition of a musical expert. Conveying and classifying expressive devices served as a fundamental stage towards the development of a set of rules regarding musical expressivity. The rule-system was established by investigating the process of a skilled musician 'teaching' a computer, and is thought to have a musical effect employed in performance either individually or as a set.

The rule-system concerns various musical parameters, such as a note's duration, frequency or direction. Among the various musical factors addressed, intonation manipulation was found a dominant feature of musical expressivity. In this regard, a distinction was made between monophonic contexts (by which, among others, 'melodic intonation' and 'melodic charge' rules were suggested) and ensemble music (suggesting, for example, 'mixed intonation for ensemble music' and 'harmonic charge' rules).

Relating data to intonation rules (study 2)

Faced with the amount of intonation discrepancies found among both 'historically informed' and 'mainstream' groups of performers, an attempt was made to examine the relation between intonation analysis data and the Sundberg et al. 'melodic intonation' and 'melodic charge'

rules (study 2). Such examination was based on the supposition that intonation deviations were related to musical expressivity and to performers' musical intuitions. Accordingly, one would assume that intonation modifications are related, among other aspects, to cases of significant 'melodic charge' and 'melodic intonation' values.

Study 1

Introduction

Previous studies have pointed to the limited influence of theory over practice where intonation of non-fixed pitch instruments is concerned. Research has shown that non-fixed pitch instrumentalists do not tend to abide by one specific tuning system, be it Pythagorean, just or equal (Nickerson, 1949, Sundberg, 1982, Karrick, 1998). Intonation discrepancies were found to be connected to a wide spectrum of influences, such as the effects of vibrato (Winckel, 1967), melodic direction and context (Edmonson, 1972, Sogin, 1989, Rakowski, 1990, Umemoto, 1990, Fyk, 1997), anatomical limitations (Small, 1937), large intervallic skips (Small, 1937, Dobbins and Cuddy, 1982, Rakowski, 1990) or even typical rehearsal settings (Morrison, 2000). The propensity was mostly towards a sharper pitch than the equally tempered value (Small, 1937, Shackford, 1961, Ward, 1970, Geringer, 1978, Sundberg, 1982).

Pitch deviations were detected in performances of both western and non-western music, as well as in different genres of musical expression (Cohen, 1969, Owens, 1974).

As mentioned above, a worldwide survey of a large group of 'historically informed' performers has been conducted, aimed in examining performers' attitudes in regards to principal factors of their

craft. It was based on personal interviews with 25 prominent performers (most of whom are world known soloists or teachers of the highest caliber), and a mailed questionnaire responded by 227 professional performers from whole over the world. Results pointed to the considerable importance given by all to the reconstruction of various historical elements of practice. 91% of the performers who took part in the survey declare reading and being acquainted with musicological sources (such as historical treatises, scholars' theoretical findings and directives etc.) as being a dominating factor in their practice. In regards to intonation, among the 139 non-fixed pitch instrument players who took part in the questionnaire (strings and winds), 79% claim to be using temperament and intonation which they considered as relevant to the historical repertoire. Among the 17 non-fixed pitch instrument players who were personally interviewed, 93% consider the use of historical temperament and intonation as being of considerably importance (Ornoy, 2002).

Having looked at performers' declarations in regards to intonation, analysis of recordings has been made in order to observe to what extent and by what means they are carried out.

Method:

Table 1 displays the list of analyzed recordings.

Table 1: List of analyzed recordings (The sign * is used for indicating performers considered as belonging to the 'mainstream' group. Performers are placed in chronological order within their instrument):

Performer	**Rec. Date**	**Rec. issue and label**
Maxence Larieu (Flute) *	1967	Philips, 438 809-2
Auréle Nicolet (Flute)*	1969	Archiv, 2533 368
Frans Brüggen (Flute)	1975	SeOn, 71964
Wilibert Hazelzet (Flute)	1982	Archiv, 2742 007
Barthold Kuijken (Flute)	1988	Deutsch Harmonia Mundi, 77026
Janet See (Flute)	1991	Harmonia Mundi, 907024.25
Noam Buchman (Flute) *	1998	JMC, SP3
Pablo Casals (Cello)*	1938	EMI, CHS7 61027 2
Paul Tortelier (Cello)*	1963	EMI SLS 798
Nicolaus Harnoncourt (Cello)	1970	The Musical Heritage, B-272-274
Anner Bylsma (Cello)	1979	SeOn RCA, SB2K 60880
Mischa Maisky (Cello) *	1985	Deutsche Grammophon, 445 373-2
Pieter Wispelway (Cello)	1989	Channel Classics CCS1090
Anner Bylsma (Cello)	1992	Vivarte-Sony Classical, 48047
Peter Bruns (Cello) *	1997	Opus 111, 30-176/177

Analysis was made using the Melograph of the Laboratory for Musicological Research of the Hebrew University. The Melograph displays each of the analyzed sound's fundamental frequencies in the

form of a melogram. Calculating each of the sound's average frequency determines its relative pitch. Thus the Melograph can provide information in regards to the standard pitch and temperament system being used by the performer.

Fundamental pitches are visually represented on the computer screen by a series of dots. The dots occur at regular intervals (a dot every four milliseconds), hence a full note's duration will appear as a series of dots displayed against a horizontal grid. In order to provide a standard for interpretation, a note's determined pitch was deduced from the average frequency of its representative dot cluster; dispersed dots representing blurred data were omitted from final calculation. Such, for example, might occur during a note's edge, when its consecutive note is overlapped in the recording process. Note, however, that the use of pitch vibrato should not have affected final analysis due to its visualization as extended frequency proportionally displayed on both sides of the grid.

Previous studies have shown that useful information gathered through the use of the Melograph could only be detected for small ranged, relatively slow monophonic repertoire (Dahlback, 1958, Cohen & Katz, 1968, Cohen, 1969, List, 1974, Moore, 1974). Hence, the repertoire chosen for analysis consisted of two of J.S.Bach's Sarabandes from the solo Flute suite in a minor (BWV 1013) and solo Violoncello suite in c minor (BWV 1011).

The analysis was made through the examination of the interval sizes made by each performer: each of the sampled notes of both excerpts was calculated for its average frequency (in Hertz), followed by the calculation of the interval sizes formed by each pair of successive notes (in cents). Blurred or unintelligible notes by which frequency could not be clearly detected by the Melograph were omitted from the data. In several cases the examination included non-successive intervals, based on

the supposition that intonation awareness is tied to significant harmonic contexts. Thus, for example, in the a minor arpeggio of bar 1 of the Flute Sarabande, the notes B4 and G♯4 function as passing notes; the chord's structural notes (A4, C5, E5) are assumed here to be executed according to their harmonic function rather than to their relation with their adjacent neighbors.

Analysis included the sizes of minor and major 2nds (N=62, N=59 respectively), 3rds (N=58, N=48), perfect 4ths (N=37) perfect 5ths (N= 52), minor and major 6ths (N=15), augmented 4ths and diminished 5ths (N=34), 7ths (N=12) and 10ths (N=8). 385 intervals were analyzed for their manner of execution among the 'historically informed' group of performers, and 368 intervals were analyzed among their 'mainstream' peers.

The values denoted as representing the historical practice (J.S.Bach's approximate mean tone temperament) were obtained by calculating the suggested size of each interval in accord with Werckmeister's model dated 1691 ('Werckmeister III') as well as with contemporary models whose period of publication and circulation is considered relevant to the production dates of most of the analyzed recordings (Kelletat, 1960, Kellner, 1977, Barnes, 1979). Table 2 presents the approximate alterations in the size of fifths and major thirds compared to their pure sizes as offered by each of the aforementioned models, out of which the analyzed interval sizes were deduced.

Table 2: suggested alterations from pure rate in cyclic order of fifths, representing J.S.Bach's meantone temperament system (Barnes, 1979).

Narrowing of fifths (in cents):

	E♭	B♭	F	C	G	D	A	E	B	F♯	C♯	G♯
Werckmeister III (1691)	0	0	0	6	6	6	0	0	6	0	0	0
Herbert Kelletat (1960)	0	0	0	2	6	6	7	3	0	0	0	0
Herbert A. Kellner (1977)	0	0	0	5	5	5	5	0	5	0	0	0
John Barnes (1979)	0	0	4	4	4	4	4	0	4	0	0	0

Widening of major thirds (in cents):

	E♭	B♭	F	C	G	D	A	E	B	F♯	C♯	G♯
Werckmeister III (1691)	16	10	4	4	10	10	16	16	16	22	22	22
Herbert Kelletat (1960)	20	14	8	1	0	6	12	19	22	22	22	22
Herbert A. Kellner (1977)	17	12	7	2	7	7	12	17	17	22	22	22
John Barnes (1979)	14	10	6	6	10	10	14	18	18	22	22	18

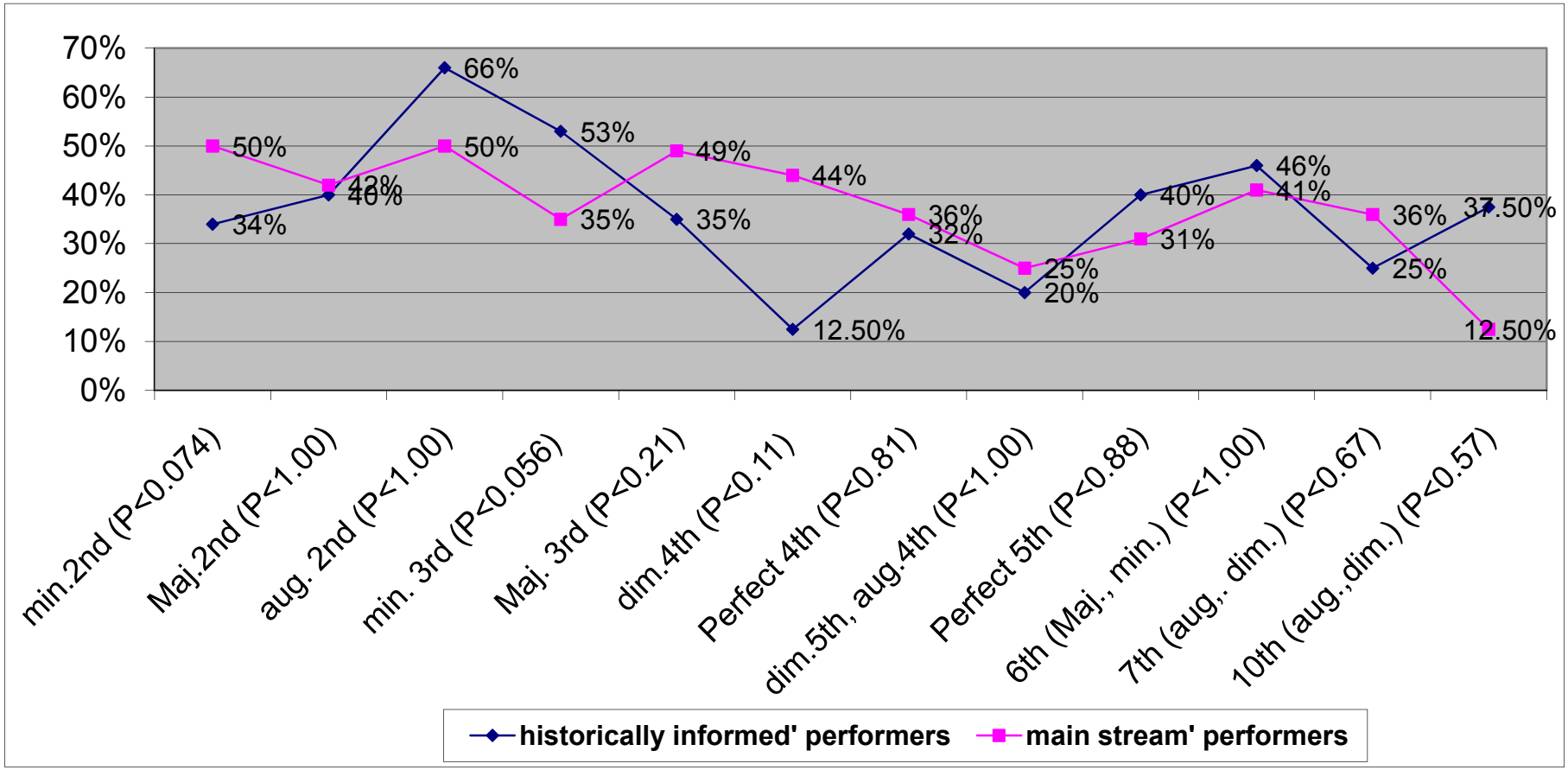
The proportions of deviation from historical practice were compared between the two study groups for each interval separately by means of Fisher's exact test. Comparison was used to a chance proportion of 50%.

Results and Discussion:

Results have shown similarity between both groups: among the 'historically informed' group 38% of all examined intervals (N =146) deviated from what could be regarded as the historical practice, while 39% deviation (N =146) was found among their 'mainstream' colleagues. No significant differences were found between the two groups in all cases ($P>0.05$).

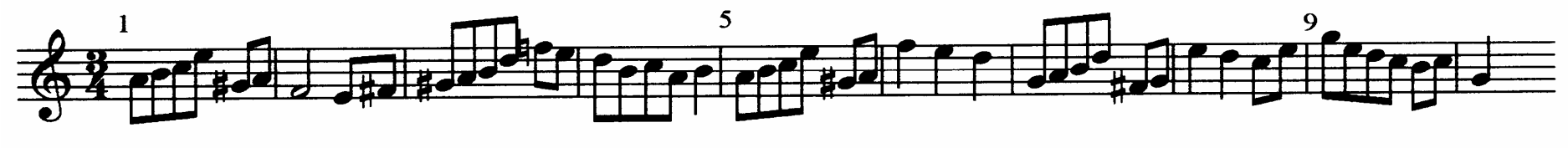
Figure 1 summarizes the amount of deviations from the historical practice found among all the intervals checked.

Figure 1: Deviations from historical practice.



Similarity between the two groups was mostly found in concordant intervals, such as 4ths, 5ths or 6ths. Of special interest is the amount of deviations found among the 'historically informed' group in regards to 5ths and major 3rds, these two intervals serving as pivotal in mean-tempered tuning. Figure 2 serves as an example for the size of 5ths as carried out by flutists (in cents). The lower row indicates the size of intervals representing the historical practice. Note that the intervals singled out in the performers' columns as not matching the historical practice are those deviating 10 cents and above scholar's directives. This agrees with human hearing sensibility in high range, detecting pitch differences from approximately 5 cents and above (Cohen & Katz, 1968, Sundberg, 1982, Sundberg, Fryden & Askenfelt, 1983. Karrick, 1998). Thus, 10 cents serves as an effective range assuring that the anomalous intervals are noticeable to the ear.

Figure 2: Melograph Analysis of 5ths: Bach's Flute Sarabande (BWV 1013)



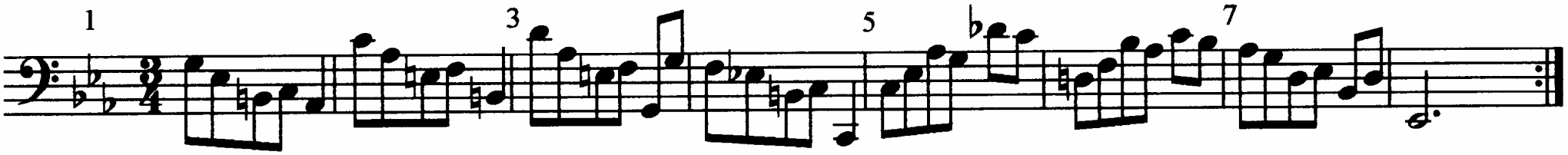
	A4-E5	E5-A4	A4-E5	E5-A4	D5-G4	G4-D5	D5-G4	C5-G5	G5-C5
Lariue*	**678**	**701**	**699**	****	****	**701**	**705**	****	**701**
Nicolet*	**708**	**712**	**709**	**705**	**674**	**680**	**706**	**680**	**719**
Brüggen	**682**	**682**	**700**	**696**	**709**	**706**	**711**	**668**	**664**
Hazelzet	****	**697**	**694**	****	**700**	****	****	**731**	**728**
Kuijken	**701**	**711**	**711**	**715**	****	**722**	**732**	****	**709**
See	****	****	**700**	**704**	**702**	**710**	**704**	**687**	****
Buchman *	**700**	**708**	**704**	**700**	**729**	**688**	**710**	**697**	**697**
Scholars' directives	**695-702**	**695-702**	**695-702**	**695-702**	**696-98**	**696-98**	**696-98**	**696-700**	**696-700**

= Intervals deviating 10 cents or more from scholars' directives.

The sign * is used for indicating performers considered as belonging to the 'mainstream' group. The sign \ indicates undetectable data.

Similarity between the two groups of performers was also found in the manner of execution of the aberrant diatonic intervals, by which approximately 37% of the intervals were carried out in accord with scholars' directives. Such accordance, for example, could be traced in the excessive widening of major thirds above their just size (386 cents), a practice considered by most scholars as corresponding to J.S. Bach's standard temperament system (Barbour, 1947, Donington, 1963, Barnes, 1979, Lindley, 1980, Lehman, 2005). Figure 3 serves as an example for the size of major 3rds as carried out by the cellists. In this example Harnoncourt and Bylsma's widening of the thirds (bar 5) is in accordance with historical practice, while Bylsma's diminution of that interval in his later recording (bar 2) is not. Note that here the intervals singled out in the performers' columns as not matching the historical practice are those deviating 15 cents and above scholars' directives. This is due to human hearing sensibility, by which pitch discrimination ability decreases in the lower range.

Figure 3: Melograph Analysis of Major 3rds: Bach's Cello Sarabande (BWV 1011)



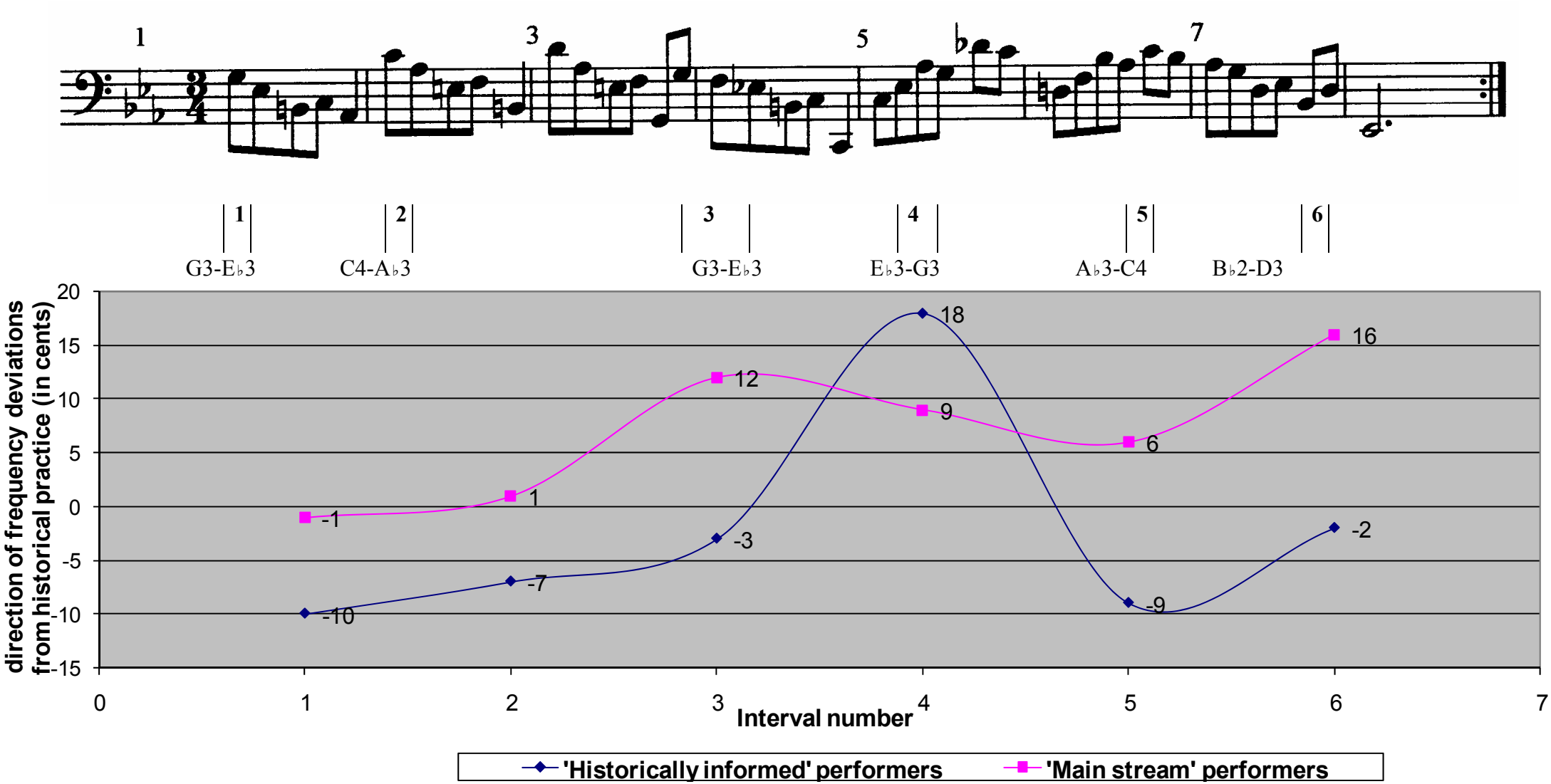
Casals*	**408**	**411**	**402**	**419**	**428**	**410**
Tortelier*	**416**	**405**	**430**	**401**	**425**	**418**
Harnoncourt	**397**	**403**	**397**	**423**	**406**	**398**
Bylsma, 79	**391**	**408**	**403**	**453**	**393**	**396**
Maisky*	**388**	**405**	**419**	**401**	**409**	**415**
Wispeleway	**395**	**400**	**386**	**386**	**393**	**389**
Bylsma, 92	**390**	**384**	**414**	\	\	**401**
Bruns*	**397**	**409**	**408**	**427**	**386**	**412**
Scholar's directives	**400-406**	**404-408**	**400-406**	**400-406**	**404-408**	**396-400**
	G3-E♭3	**C4-A♭3**	**G3-E♭3**	**E♭3-G3**	**A♭3 –C4**	**B♭2-D3**

= Intervals deviating 15 cents and more from scholars' directives

The sign * is used for indicating performers considered as belonging to the 'mainstream' group. The sign \ indicates undetectable data.

Figure 4 summarizes the direction of modifications from historical practice related to Figure 3. Notice how in most cases 'historically informed' performers are found narrowing their major 3rds below scholars' directives.

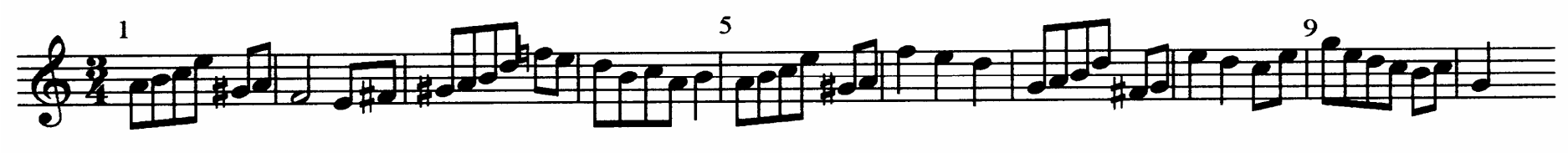
Figure 4: Direction of modifications from the historical practice- Major 3rds, Cello Sarabande.



The differences between the two groups, found to some degree in the manner of execution of discordant intervals such as 10ths, 7ths and diminished 4ths, correspond to findings regarding the manner of execution of chromatic intervals: among the 'historically informed' group 55% of the aberrant chromatic intervals have been carried out in accordance with historical practice, while such accordance was found to a much lesser degree (27%) among their ‘mainstream’ equivalents. Correspondence in that regard could be traced in the lowering of a sharpened note against raising its enharmonic equivalent. Such practice derives from the general principal expressed in historical sources, by which flats were performed a comma higher than sharps. The term 'comma' represented various values, such as in the '¼-comma meantone temperament', in which a 'comma' is approximately 41 cents. In practice, the note, say, D♯ should sound flatter than E♭ (Haynes, 1991, Barbieri, 1991, Lehman, 2005).

Figure 5 serves as an example for the size of minor 2nds as carried out by the flutists. In this example, Hazelzet’s widening of the 2nd in bar 5 corresponds to the historical practice, while Kuijken’s diminution of that interval (bar 7) is in contrast to it.

Figure 5: Melograph Analysis of minor 2nds: Bach's Flute Sarabande (BWV 1013)



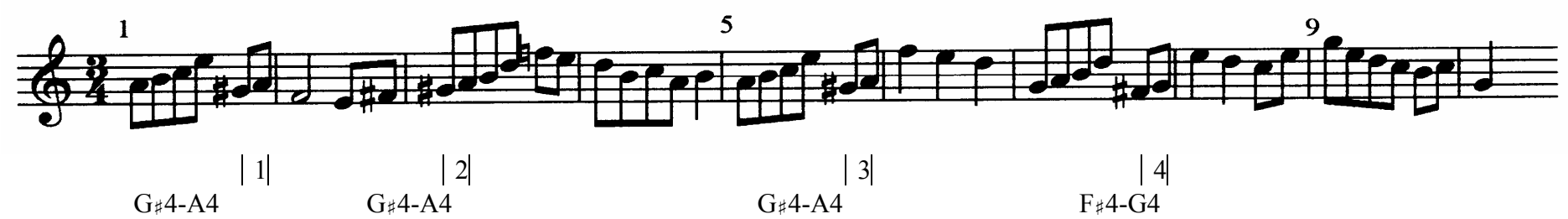
Lariue*	**91**	**92**	**122**	**123**	\	**91**	\	**98**	**98**	\	**102**	\
Nicolet*	**108**	**87**	**95**	**112**	**92**	**86**	**79**	**95**	**94**	**103**	**73**	**73**
Brüggen	**137**	**89**	**117**	**85**	**133**	**99**	**99**	\	\	**101**	**125**	**72**
Hazelzet	**94**	**109**	**101**	**106**	**115**	**103**	\	**122**	**125**	**107**	\	\
Kuijken	\	**93**	**99**	**99**	**105**	**120**	**92**	**88**	**112**	**96**	**119**	**108**
See	**102**	\	**108**	**95**	\	**96**	**88**	**86**	\	\	**112**	**105**
Buchman*	**92**	**110**	**87**	**90**	**89**	**102**	**102**	**118**	**89**	**96**	**109**	**102**
Scholars' directives	**106-114**	**96-100**	**108-111**	**96-100**	**108-111**	**106-114**	**106-114**	**96-100**	**108-111**	**106-112**	**106-114**	**106-114**
	B4-C5	**G♯4-A4**	**F4-E4**	**G♯4-A4**	**F5-E5**	**B4-C5**	**B4-C5**	**G♯4-A4**	**F5-E5**	**F♯4-G4**	**C5-B4**	**B4-C5**

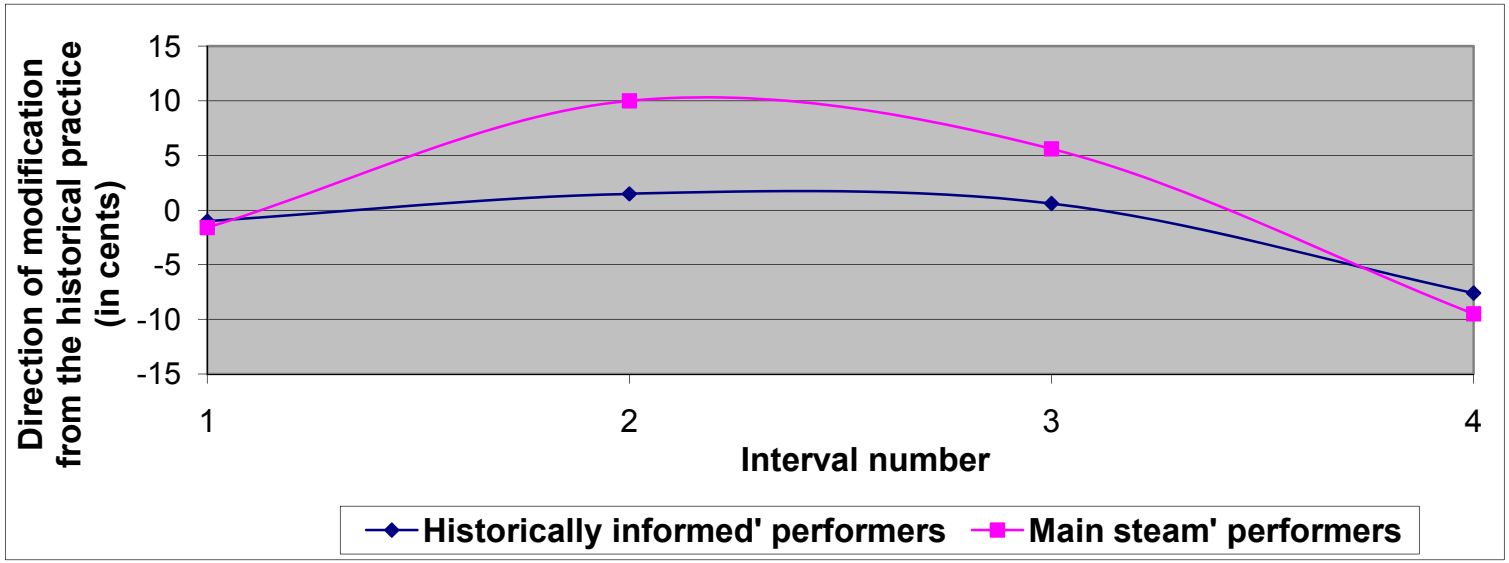
= Intervals deviating 10 cents or more from scholars' directives.

The sign * is used for indicating performers considered as belonging to the 'mainstream' group. The sign \ indicates undetectable data.

Figure 6 summarizes the direction of modifications of chromatic intervals related to Figure 5. Note that most sharpened notes examined are executed lower by the 'historically informed' performers then by their 'mainstream' equivalents. The practice of raising sharpened notes featured in the latter group derives from the Pythagorean, 'expressive' modern manner of enhancing its function as leading notes.

Figure 6: Direction of modifications of chromatic intervals--minor 2nds, Flute Sarbande.





Study 2

Introduction:

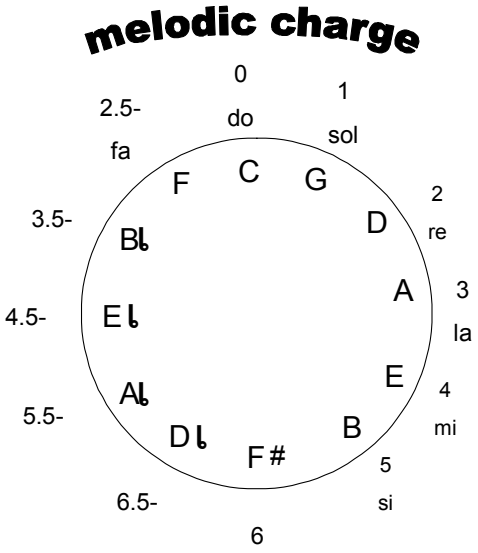
Tested on musically trained listeners, significant support for the aforementioned 'rule-system to musical expression' has been reported (Thompson, Sundberg, Friberg & Frydén, 1989). Although most rules of the overall system were found effective while implemented as a set (i.e. four or five different rules put together), in several cases application of just one rule implemented in an appropriate melody yielded significant ratings among subjects, pointing to its effect as an individual variable. Hence, while the process of creating expressivity involves a combination of various rules, and though there may be many synonyms for any one aspect of musical expression, the significance of each individual rule in affecting expression is connected to its overall musical context, and *"applying one performance rule that is very effective can be as beneficial to the performance as applying three less effective rules"* (ibid., p. 730).

Similar in texture (chromaticism) and in idiomatic characteristics (being intended for monophonic, non-fixed pitch instruments), both excerpts of this present study seem highly appropriate for examining the particular rules regarding intonation. Addressing these specific expressive devices enables evaluation of their individual significance on findings.

Since monophonic repertoire is involved, examination was restricted to the relation between ‘melodic charge’ and ‘melodic intonation’ rules, and the analyzed intonation deviations. Notes of relatively high or low ‘melodic charge’ and ‘melodic intonation’ ratings were thus examined for their frequency occurrence in real practice.

The term ‘melodic charge’ is used to describe a tone’s ‘remarkableness’ or ‘unexpectedness’ in its musical context. According to the rule's formulators, a note’s ‘melodic charge’ is a function of its position in the circle of fifths, increasing in value according to its distance from the root of the prevailing chord. Figure 7 displays 'melodic charge' values, C serving as the root of the chord. Note that distribution is asymmetrical around the circle of fifths; notes located down from the root (i.e. the circle's subdominant side) are marked negative and are greater in value.

Figure 7: Definition of 'melodic charge' by means of the circle of fifths (Sundberg, Friberg & Frydén, 1989).



Amplitude and duration were found to increase in proportion to a tone’s ‘melodic charge’ values (Sundberg, Frydén & Askenfelt, 1983, Sundberg & Frydén, 1987, Sundberg, Friberg & Frydén, 1989), while additional findings suggested correlation between interval tunings (in ensemble performances) and the melodic charge of the target note (Sundberg et al., 1989).

‘Melodic intonation’ refers to frequency deviations from equal tempered tuning in a monophonic context, connected to the number of semitones above the root of the chord (Friberg, 1991). Deviations are suggested as varying (in cents) from 0 (for the note which is the root of the chord) to 10 (for the note situated 6 semitones above the root of the chord).

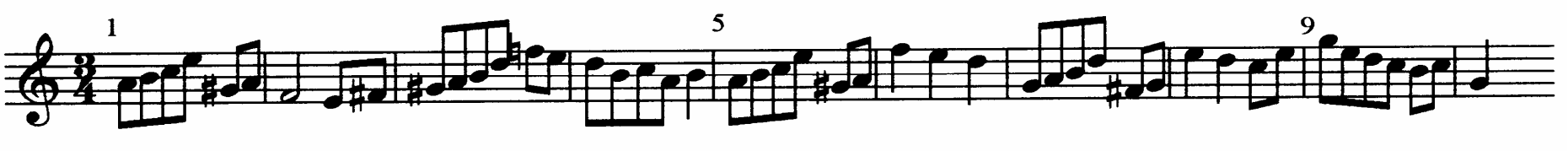
Apart for the application of the rule system to data gathered by analysis-by-measurement strategy (by which a hypothesis is formulated upon the measured data), this examination differs from previous studies in addressing two different groups of performers divided in their preferred tuning systems. Hence, while early music performers were examined for their deviations from the historical mean-tempered system, followed by comparison to ‘melodic charge’ and ‘melodic intonation’ ratings, ‘mainstream’ performers were examined in this case for their deviations from equal tempered tuning followed by such comparison.

Method:

Both 'melodic charge' and 'melodic intonation' ratings were obtained by defining each musical excerpt’s harmonic sub-texture and chord progressions. 'Melodic charge' values (marked Xmel) were calculated according to each note’s position in the circle of fifths in relation to the root of its prevailing chord. 'Melodic intonation' values (i.e. the suggested frequency deviation in cents, marked ΔFmel) were calculated according to each note’s distance in semitones above the root of its prevailing chord.

Figure 8 displays 'melodic charge' and 'melodic intonation' ratings obtained for the Flute Sarabande. Figure 9 displays 'melodic charge' and 'melodic intonation' ratings obtained for the Cello Sarabande.

Figure 8: 'melodic charge' values and 'melodic intonation' ratings (in cents): Bach's Flute Sarabande (BWV 1013)

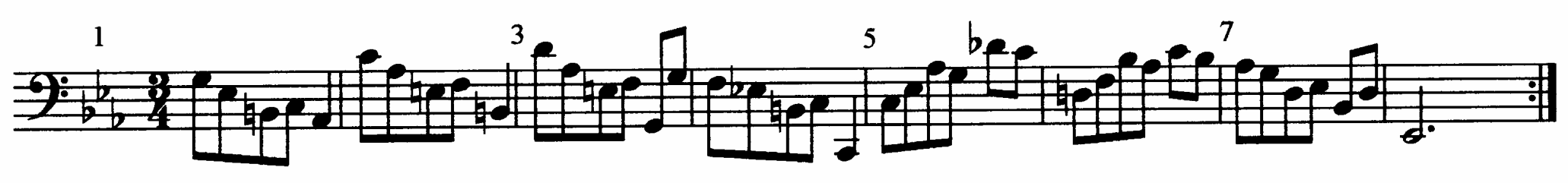


	a	b	c	e	g	a	f	e	f	g	a	b	d	f	e	d	b	c	a	b	a	b	c	e	g	a	f	e	d	g	a	b	d	f	g	e	d	c	e	g	e	d	c	b	c	g
ΔFmel ('melodic intonation')	**0**	**3**	**4**	**1**	**9**	**0**	**6**	**0**	**3**	**4**	**2**	**1**	**4**	**7**	**0**	**4**	**1**	**6**	**2**	**1**	**0**	**3**	**4**	**1**	**9**	**0**	**4**	**3**	**0**	**0**	**3**	**4**	**1**	**9**	**0**	**4**	**3**	**0**	**4**	**1**	**4**	**3**	**0**	**9**	**0**	**1**
Xmel ('melodic charge')	**0**	**2**	**-4.5**	**1**	**5**	**0**	**-5.5**	**0**	**2**	**4**	**-2.5**	**1**	**-3.5**	**-6.5**	**0**	**-3.5**	**1**	**-5.5**	**-2.5**	**1**	**0**	**2**	**-4.5**	**1**	**5**	**0**	**-4.5**	**2**	**0**	**0**	**2**	**4**	**1**	**5**	**0**	**4**	**2**	**0**	**4**	**1**	**4**	**2**	**0**	**5**	**0**	**1**

= Notes of significantly low 'melodic charge' and 'melodic intonation' ratings (Xmel, ΔFmel : 0-1).

= Notes of significantly high 'melodic charge' and 'melodic intonation' ratings (Xmel: 5-6.5, ΔFmel: 6-9).

Figure 9: 'melodic charge' values and 'melodic intonation' ratings (in cents): Bach's Cello Sarabande (BWV 1011)



	g	e	B	c	A	c	a	e	f	B	d	a	e	f	G	g	f	e	B	c	C	c	e	a	g	d	c	d	f	b	a	c	b	a	g	d	e	B	d	E
ΔFmel ('melodic intonation')	1	4	9	0	4	1	4	9	0	4	1	7	4	4	0	0	2	4	9	0	0	0	4	6	1	7	0	4	1	0	4	3	0	2	4	9	0	1	9	0
Xmel ('melodic charge')	1	-4.5	5	0	-4.5	1	-4.5	5	0	4	1	-6.5	3	-3.5	0	0	-2.5	-4.5	5	0	0	0	-4.5	-5.5	1	-6.5	0	4	1	0	-3.5	2	0	-2.5	4	5	0	1	5	0

= **Notes of significantly low 'melodic charge' and 'melodic intonation' ratings (Xmel, ΔFmel : 0-1).**

= **Notes of significantly high 'melodic charge' and 'melodic intonation' ratings (Xmel: 5-6.5, ΔFmel : 6-9).**

Since in most cases the suggested deviations according to both rules are not discernible to the unaided ear, special significance has been given to notes by which deviations of 10 cents (or 15 in the Cello's case) and above the suggested temperaments (meantone or equal, depending on the group examined) has occurred. Similarly, significance has been given to notes deviating 5 cents and less, assuming in such cases that the minor aberration was unintentional.

Fisher's exact test was used in order to compare the proportion of deviations within each group to a chance proportion of 50%.

Results and Discussion:

Results have shown no correspondence between both rules and the deviations made in practice by both groups: approximately 30% of the deviations have been found to match cases where low 'melodic intonation' and 'melodic charge' ratings were suggested (Xmel, ΔFmel 0-1; frequency deviation of 5 cents and less the suggested value). Similarly, approximately 34% of the deviations have been found to match cases where high 'melodic intonation' and 'melodic charge' ratings were suggested (Xmel 5-6.5, ΔFmel 6-9; frequency deviation of 10 or 15 cents and more from the suggested value).

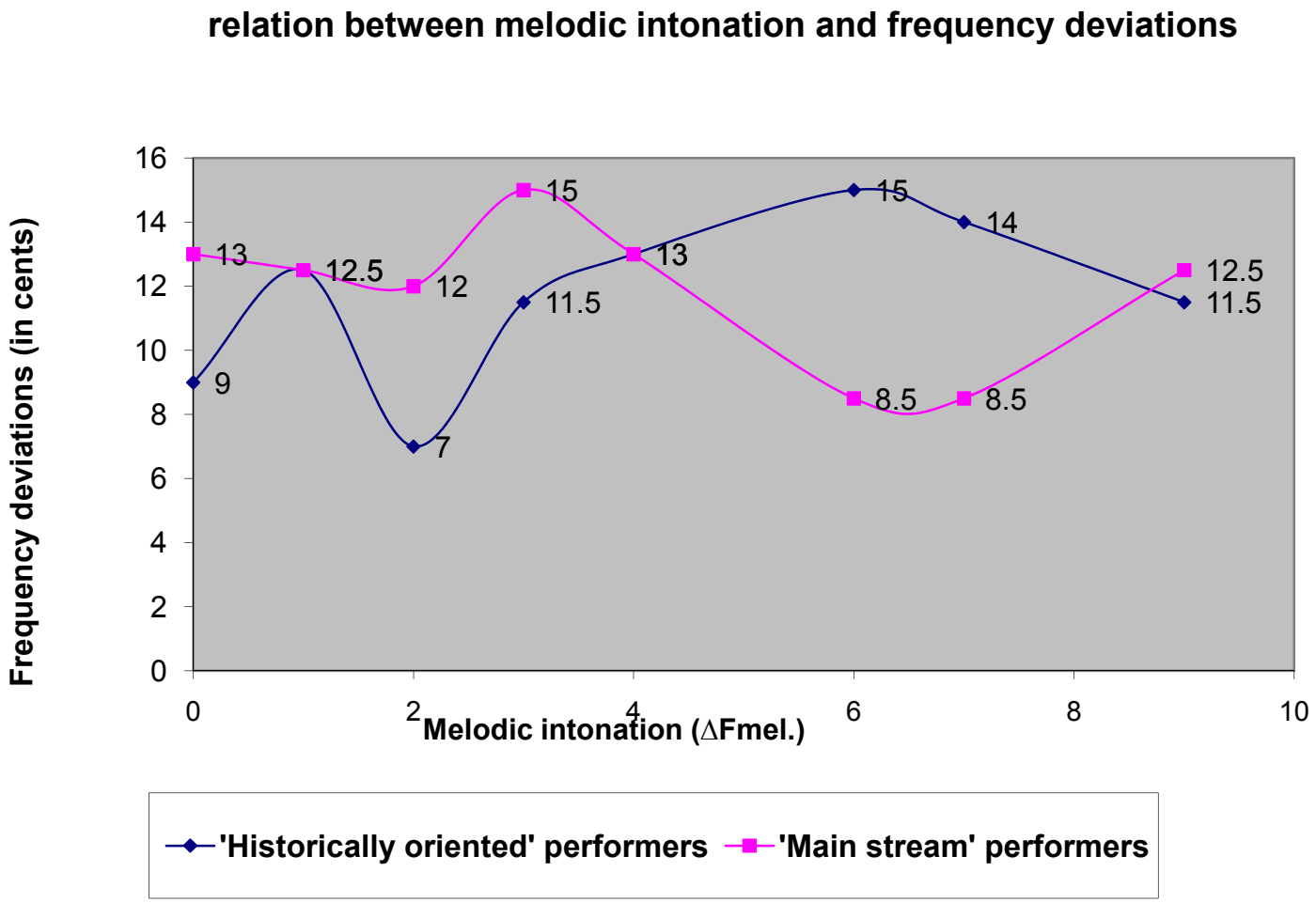
Table 3 summarizes the amount of frequency deviations found matching cases of significant Xmel and ΔFmel ratings. Note that in all cases the proportion of deviations was found significantly different from chance proportion ($P<0.05$), thus contradicting the prediction made by the rules.

Table 3: Compliance between frequency deviations and notes of significant Xmel and ΔFmel ratings.

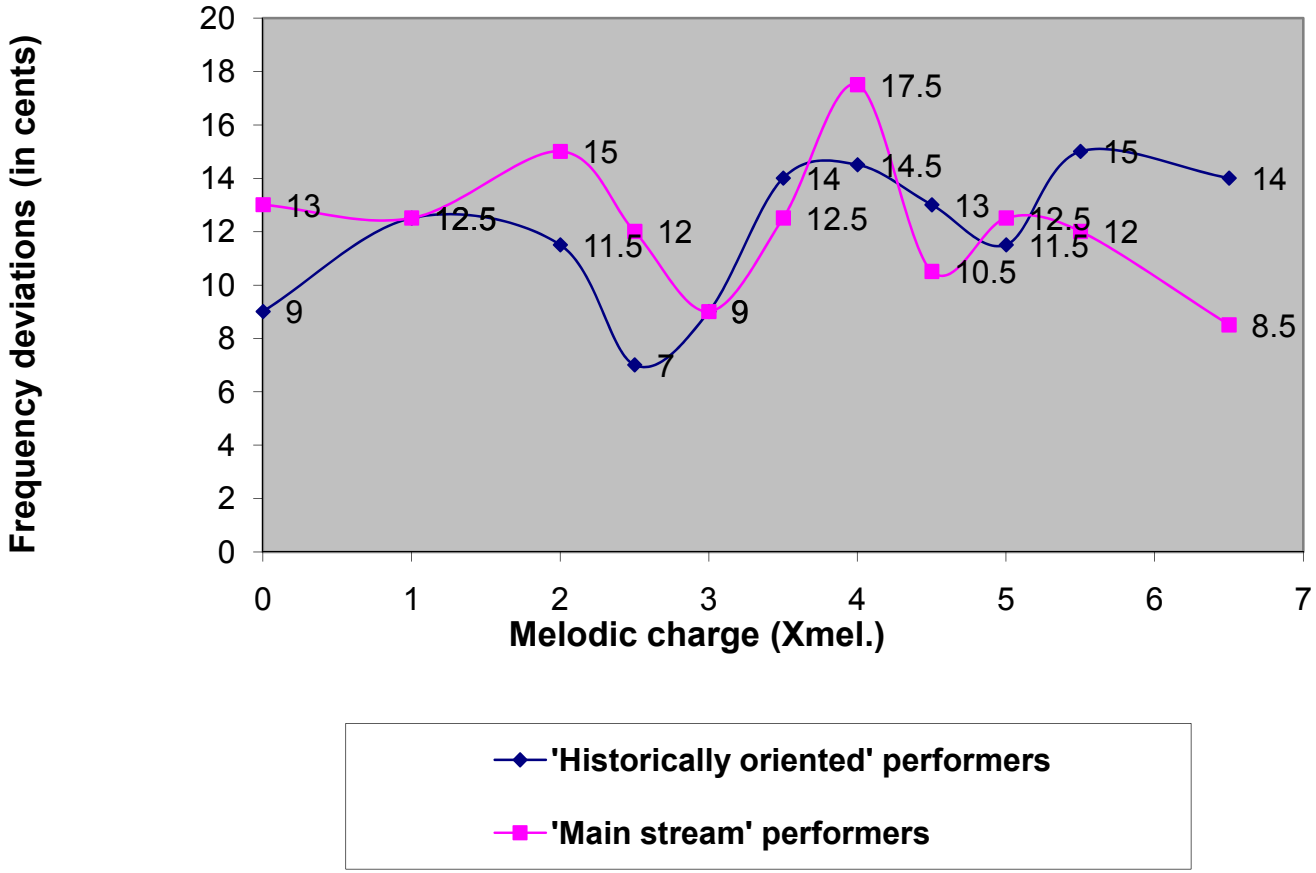
		All performers	**'Historically informed' performers**	**'Mainstream' performers**
Low Xmel, ΔFmel ratings	Distribution:	62	38	24
	Frequency:	30%	36%	24%
	Total dist.	205	106	99
	P value:	P<0.0001	P<0.0046	P<0.0001
High Xmel, ΔFmel ratings	Distribution:	35	18	17
	Frequency:	34%	34%	35%
	Total dist.	102	53	49
	P value:	P<0.002	P<0.027	P<0.044

Figure 10 displays relationships between 'melodic charge' and 'melodic intonation' values and frequency deviation found among both groups.

Figure 10: Relation between rules and measured frequency deviations:



relation between melodic charge and frequency deviations



Note that while low or high Xmel and ΔFmel ratings do not seem to match the examined frequency deviations, both groups differ in their relation to close-to-high 'melodic intonation' ratings (ΔFmel: 6-7). This is due to the different manner of execution of chromatic intervals practiced by each group. Hence, notes such as A♭3 or D♭4 in the Cello Sarabande excerpt (mm. 3, 5) are carried out by the 'historically informed' performers fundamentally higher than among their 'mainstream' peers, the latter lowering their flats in the Pythagorean, 'expressive' modern manner.

The significant frequency deviations seen among the 'mainstream' group in cases of notes of average 'melodic charge' values (Xmel: 3.5-4) is connected both to the manner of execution of chromatic intervals discussed above, and to the general tendency mentioned earlier towards increasing the size of large intervals, some of which constitute several notes valued Xmel: 3.5-4 (minor and major 6ths in the flute Sarabande excerpt, minor 7^{th} in the cello Sarabande excerpt).

General Discussion

Apart from their wide implications on the study of early music performances, intonation analysis results reinforce conclusions made in many studies, pointing to the limited influence of theory over practice in regard to intonation of non-fixed pitch instruments.

Indeed, contrary to early music performers' declarations, it now seems that intonation is more confined to idiomatic or contextual limitations than to theoretical directives. These findings, together with the similarity in intonation discrepancies noted among their 'mainstream' colleagues (apart for the realization of chromatic intervals), suggests that

intonation should not be regarded as a distinctive element of practice where early music performances on non-fixed pitch instruments are concerned.

Following the second study, it seems that a note's 'melodic charge' and 'melodic intonation' value have limited effect on intonation carried out in practice.

Certain considerations should be made while examining findings: since several rules have been said to have simultaneous influence on a performance, no deductions should be made as to the reliability of any of the rules that might affect intonation other than the two tested here. Moreover, the cumulative effect of the rules as a set of cues, by which each of its components' values are closely connected to its musical context, might suggest in this case the small significance of the two rules examined, but not their overall abolishment. In order to fully examine the cause for intonation discrepancies found in data, additional, more comprehensive study should examine the effect of each of the various rules, statistically controlled for various other influences on intonation unrelated to the rule-system, such as physical constraints, the effects of vibrato, inherent idiomatic sub-features differing between 'historically oriented' (baroque flute or cello) and modern instruments, etc.

One should additionally bear in mind that the rule-system generators have pointed from the start to the numerous ways of performing musically, regarding the rules as merely descriptive of an expert's interpretation in a local musical context. Hence it is not unlikely that in both musical excerpts expressive devices other than those presented by the rule-system have been used, connected to various idiomatic, textual or non-textual aspects of musical performance.

Nevertheless, findings have clearly failed to show significant influence of a note's 'melodic charge' and 'melodic intonation' value on its performed intonation.

Such findings might very well suggest the possible discrepancy between the two methods of analysis, for data collected from actual performances, as in the present case, have failed to coincide with suppositions based on analysis-by-synthesis strategy. The findings hence raise questions of great importance as to the possible gap between performers' expressive tools employed as an outside assessor and the actual devices used by him in practice. It is reasonable to suppose, for example, that in the case studied here, confinement to idiomatic and technical limitations, such as inherent tuning deficiencies of the instrument or acoustic distortion in the recording studio, affect performers' expressive actions in both conscious and subconscious levels. Faced, theoretically, with similar interpretations as an outside evaluator, the same performer might very well suggest quite different expressive devices. Future research aimed at further investigation of such a hypothesis is sure to embrace the performer-as-teacher phenomenon, addressing many pedagogical and artistic actions such as master classes, conducting, instrumental teaching etc.

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