

The Rhythm of Gregorian Chant: An Analysis and an Empirical Investiga- tion

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Introduction

Any discussion of the authentic rhythm of Gregorian Chant must deal with the duration of individual notes. The two main theories of chant rhythm, semiology and mensuralism hold that different durations can be discerned in plainchant. However, whereas mensuralists believe in strictly measured and proportional durations, Gregorian semiology defends the proposition that, if an isolated note occurs on a syllable, this note has syllabic duration (*temps syllabique*). As Cardine (1970: 10), the founder of this theory, explains, this duration concerns ‘une durée essentiellement liée à celle du texte et à son exacte prononciation’.

Nuanced Durations

The reason for this view, which is believed to also hold for non-isolated notes (see later), is simple. The rhythm of Gregorian chant, which is essentially vocal music, can be only realised in the symbiosis of the text and the melody, or, more precisely, of the syllable and the sound. Hence syllabic time cannot be measured rigorously:

‘Il jouit d’une certaine élasticité, conséquence des modifications qui lui sont imposées par le «poids» divers des syllabes elles-mêmes. Il suffit de prononcer simplement les exemples suivants pour constater la différence de durée des syllabes:

1. Veni Domine
2. non confundentur
3. dii eorum — filii tui’ (Cardine 1970: 10).

Whereas case 1 illustrates the normal syllabic beat, the durations of the syllables in the second and third cases are associated with greater and smaller values, respectively. Cardine (1970: 16) speaks, in case 2, of the *temps syllabique augmenté* and, in case 3, of the *temps diminué*. In the notation of St. Gall, an increased duration of an isolated note might be indicated by the addition of a horizontal *episema* (a short dash) or by writing the letter *t* (*tene*: to hold) to a *virga* or *tractulus*, a reduced value by writing the letter *c* (*cito* or *celeriter*: to be sung quickly) to these signs. According to Cardine, both the *episema* and the letter *t* were used to denote important monosyllabic words or accented syllables, and the letter *c* to bring out the difference with a subsequent accented syllable. The dependence of the text is also stressed in research by Smits



van Waesberghe (1942b: 626). An accented syllable, for instance, is simply not found to be notated by a virga with *celeriter*, whereas an unaccented syllable never receives a virga with *t*. However, these findings do not warrant the conclusion that the letters *c* and *t* and the episema in syllabic melodies are always applied in a consistent and unambiguous manner. Important monosyllables, for instance, may be equally represented by a virga without *t* or the episema. Like the virga or tractulus itself, these additional signs or letters are believed to have no fixed meaning regarding duration. Rather, according to Cardine (1970: 12) and Smits van Waesberghe (1942b), the episema would only be notated if there is some danger to neglect an important accented syllable.

Equally important in Gregorian semiology is Cardine's (1970: 22, 145) assertion that, in neumes of more than one note, similar relationships exist with the normal syllabic beat or its diminished form. The *pes quadratus*, for instance, in the notation of St. Gall, is believed to represent two times the *temps syllabique normal*, whereas the *pes rotundus* is considered to equal two times the *temps syllabique diminué*. In support of this view, Cardine observes that, if different words are applied to the same melody, two successive syllables provided with a tractulus and a virga, respectively, may be replaced in another text by one syllable, this time, however, supplied with a *pes quadratus*. To further claim that all individual notes in neumes of at least two notes show syllabic duration, Cardine (1985) stresses the observation that the same neumatic signs, namely the *punctum*, the *uncinus*, and the *uncinus* with *t*, that were used for isolated notes to indicate several nuances in Codex Laon 239 (see the [Appendix](#) for the codices mentioned in this article) also occur in neumes of more than one note. Hence the flexible durations that apply to an isolated virga, tractulus, uncinus or punctum are assumed to be also applicable to each individual note in more complex neumes. However, in the latter case, these flexible durations are merely regarded as *text analogical*. By this it is meant that the individual notes of a neume with at least two notes are held to display the same nuanced duration values as the syllables of a well-articulated text. According to Göschl (1985: 82), for instance, the notes that form part of a neume of more than one note must be performed '*wie Silben einer Wortmelodie und ebenso differenziert wie diese*'. This view, however, though often defended, is untenable. Whereas isolated notes, especially in chants that are largely composed in syllabic style, have duration values that directly mirror the phonetic qualities of the syllables (Göschl 1985: 46), no such relationship exists in the case of the individual notes of a neume of at least two notes. Even the more moderate view of Hakkennes (1989: 90, 92), according to which the notes in non-syllabic melodies, compared with isolated notes, show a lesser degree of differentiation owing to the absence of consonants, cannot be accepted because no text characteristics are directly referred to. Hence the actual durations are impossible to determine. Nevertheless, one may still claim that some individual notes have longer, and others shorter, durations. The lengths in these cases, however, are only dependent on such features as (i) the shape of the neumatic sign, say, a *torculus quadratus* instead of a *torculus rotundus*, (ii) the presence of an expressive neumatic break (see [Cardine 1961](#)), or (iii) the addition to the neumatic sign of an episema, or of the letters *c* or *t*.

Fixed Note Values

With the introduction of strictly measured durations, whether for isolated notes or for notes within neumes of at least two notes, no problems exist as mentioned above. Here we arrive at the so-called *mensuralist* or *proportionalist* theories of Gregorian plainchant that are proposed, for instance, by Wagner (1912), Jeannin (1925), Vollaerts (1960), and Murray (1963)¹. Though differing in several respects, most of these theories adhere to the view that at least two kinds of note values must be discerned, namely short ones of one beat and long ones of two beats (Rayburn 1981). In some theories, however, additional proportional note lengths are considered, for instance, a third value to indicate further prolongation (Apel 1958: 129). For the distinction between the two basic note lengths, mensuralists point to the observation that the neumatic signs for isolated notes in manuscripts from various countries and regions do highly correspond to each other, despite differences in notation. Thus it appears that the *punctum* (short) and the *uncinus* (long) in Codex Laon 239 (see the [Appendix](#)) nearly always correspond to the tractulus or virga with *c*, and the tractulus or virga without *c*, respectively, in the notation of St. Gall (for example, Codex Einsiedeln 121). So, even assuming that the rhythm of Gregorian chant shows a lot of different shadings, one must conclude that these nuanced durations apparently are related to two clearly distinguishable categories of short and long notes. However, the flexible durations in both categories are denied in mensuralist theories, with the effect that usually only short notes of one beat and long notes of two beats remain. The medieval music treatises of particularly the tenth and eleventh centuries play an important role in defending this view. Citing, for instance, the *Commemoratio Brevis*, a document from the tenth century, Murray (1961) mentions the following instructions to which the singer must comply:



Therefore let no inequality of chanting mar the sacred melodies; ... In fact all the longs must be equally long, all the shorts of equal brevity ... And in accordance with the length-durations let there be formed short beats, so that they be neither more nor less, but one always twice as long as the other ... because assuredly every melody is to be carefully measured after the manner of metre.

This measuring after the manner of metre, Murray ([1961](#)) explains:

can only mean one thing: distinguishing the component elements (the notes), as the syllables are distinguished in metre, into longs and shorts, the former being twice the length of the latter.

Remarkably, in mensuralist theories, durations of one or two beats are often assumed to also apply to isolated notes. For instance, in Murray's ([1963](#)) melodic transcriptions of chants that are composed in syllabic style, extensive series of subsequent isolated signs, whether *virgae* or *tractuli*, are represented by notes that have the same (long) duration. Such a view, however, is not in agreement with the medieval treatises on music, at least not those stemming from the ninth century. Indeed, both Wagner ([1916](#)) and Jeannin ([1930](#)) have argued that, in musical treatises from that period, mention is not only made of the chant's *metrum*, referring to long and short feet, but also a free-flowing *rhythmus* that, according to, for instance, Remigius of Auxerre (ninth century), is determined by 'the mere consonance of words ... bound by no law and composed of no specified feet'. The same distinction was offered by the ninth-century author, Aurelianus Reomensis, who mentions that *rhythmus* 'inquires into the joining of the words, whether the sound hangs together well or ill', thus noting that the manner of singing (*modulatio*) in chant must be adjusted to the natural rhythm of speech, whereas *metrum* follows a 'rational scheme of feet' ([Fassler 1987](#); [Kohlihaas 2001](#)). It is true that both terms had other meanings in other times (see, for example, [Crocker 1958](#); [Stevens 1986](#)), but the fact that Remigius and Aurelianus wrote about music in the flowering period of Gregorian chant attaches special significance to their descriptions. It might also be true that the concepts of *rhythmus* and *metrum* are not completely different, because several authors since the time of St. Augustine have indicated that all metre is rhythm, but not all rhythm is metre. According to Bede (eighth century), for instance, applying these terms to poetry, 'metrical verse is a quantitative system with a rhythmical beat, while rhythmic verse has a rhythmical beat without a quantitative system' ([Heikkinen 2012](#)). Realising that the distinction between *metrum* and *rhythmus* basically refers to the presence or absence of measured note values, we may conclude with Wagner ([1916](#)) 'daß der Ausdruck "rhythmisch" sich auf syllabische Bewegungen bezieht, wo der Text bestimmend ist, und "metrisch" auf Melismenfiguren'. Thus, as this author claims, the freedom that characterises the *rhythmus* of chant is not in agreement with 'die unkünstlerische Praxis derer, die in den syllabischen Gesängen den Silben einen mathematischen Gleichwert beimessen'. As we will see below, there are some indications, not mentioned in the prevailing literature, that single isolated notes in the context of otherwise non-syllabically-composed chants must be performed in a slower tempo than isolated notes of truly syllabic melodies. Still, both kinds of isolated notes do manifest flexible durations.

Other Objections

Besides the critical remarks mentioned above, other objections have been formulated against the mensuralist view. Both Mocquereau ([1926](#)) and Smits van Waesberghe ([1942a](#)) were of the opinion that medieval treatises approach the rhythm of Gregorian chant by assuming a clear correspondence with ancient Greek music theory, which was the reason that these treatises only speak of fixed durational proportions. However, this notion is unjustified, at least to the extent that ancient music theory certainly is not the only source from which the treatises were drawn. As Rayburn ([1981](#)) rightly asserts:

Mocquereau's attitude ... is incredible, for certainly the monks and writers of the ninth century knew more about the subject at hand than did those of the nineteenth and twentieth centuries; they were monks who sang every day in choir the very music about which they wrote.

That measured note values were also emphasised in practice is sometimes reported in the treatises themselves. For instance, in the *Scholia Enchiriadis*, a treatise from the tenth century, practical exercises are described that may be of help in discriminating between notes of 1 beat and notes of 2 beats.



Another more important objection to mensuralist theories was also raised by Smits van Waesberghe (1942b). According to this criticism, the idea of a distribution of short and long notes in Gregorian chant is certainly appropriate, but one should not forget that these notes were not sung in a strict proportional way by distinguishing notes of one beat and notes of two beats. Smits van Waesberghe's (1942b: 632) principal argument in this respect is that, in the notation of St. Gall, so many neumatic signs occur, whether or not in combination with the letters *c*, *t*, *m*, *cm*, *tm*, *cb* or *tb* (*m*=*mediocriter*: just a little; *b*=*bene*: thoroughly), these signs and letters cannot simply mean only two durations. It must be noted, however, that the application of different signs is wholly irrelevant here. For, apart from the addition of episemata or letters, these signs, at least in the case of neume figures of two or more notes, only indicate the presence of short or long notes, even when the terms short and long refer to flexible durations. Nevertheless, the addition of letters or of an episema might indeed give way to a critical attitude towards mensuralism. In his objections to Vollaerts' (1960) mensuralist theory, Smits van Waesberghe (1960) points to the fact that the letter *t* in the notation of St. Gall is so often added, even to long notes, that these additions can hardly be called superfluous. More reasonably, for Smits van Waesberghe, 'these notes would seem to have many more duration nuances than are conceded in the 2:1 ratio theory'. Likewise, if short notes always would have an identical length, what then is the meaning of the letter *c*, which so frequently is added to a short note?

May we call such care "unnecessary", or assert that it was exercised only "to help ignorant singers"? And what of the other letter combinations appended to neumes?(Smits van Waesbergh 1960)

Certainly, the theory of the ignorant singers (Vollaerts 1960) is out of the question. Choral conductors and soloists, the monks that, at least initially, were the only ones that had books with neumatic signs at their disposal, cannot be called ignorant. However, it is also possible to criticise Smits van Waesberghe's (1960) suggestion that the letters *c* and *t* must be necessary because of his belief that these letters result in an extra shortening or lengthening of an already short or long note. It is revealing, in this respect, that the meaning of the letter *c*, even according to Smits van Waesberghe's (1942b: 671) own research, is often negative, which means that no extra shortening is implied, but only a contrast with a longer note. This superfluity, just as the one indicated by the letters *a* (= *auge*: lengthen the note; in Laon 239) and *t* or by the episema, becomes even more apparent if several manuscripts are compared, not only the ones using the same notation, but also manuscripts that differ from each other in that respect. The same applies when similar musical passages are compared in one manuscript (see Vollaerts 1960: 146). For, in all these circumstances, the use of the letters *c* or *t* and the episema is so haphazard that only one conclusion remains, namely that these letters and the episema, compared with the neumatic signs themselves, imply an alternative way to indicate short and long notes, and that these additions thus seem indeed unnecessary. The equivalence of both manners to indicate the length of the notes is also supported by Aribio's treatise *De Musica* (eleventh century), in which the rhythm of Gregorian chant is explained not by discussing the various neumatic signs, but by addressing the fact that, in previous times, short notes were often indicated by the letter *c*, and long notes by *t* (see below for the letter *m*). However, having said so, one must be aware that the letters *c* and *t* are not always superfluous. It is certain that, if the letter *t* (and this applies also to the episema and the letter *a* in Laon 239) is added to a short note, this letter lengthens this note, whereas the letter *c*, if joined to a long note, makes this note short (see, for example, Vollaerts 1960: 155). The use of the letter *c* (and this applies also to the *t* and the episema) to indicate a particular contrast with another note was already mentioned above.

While maintaining the proportionalist theory that the letter *c* refers to a short note of one beat, and *t* or *a* or the episema to a long note of two beats, Murray (1961: 6) also mentions that:

The matter is perhaps not quite so simple when the letters *m* (*mediocriter*) and *b* (*bene*) are combined with *t* or *c*, as sometimes happens in some of the St. Gall manuscripts.

Although once more trying to defend the mensuralist view by stating that the term, *mediocriter*, stands for *in medio*, which was translated as 'precise, exact, without exaggeration', Murray obviously has no eye for the usual interpretation of the letter *m* as a modifier of both melodic and rhythmic letters. Just as *m*, combined with, say, the letter *s* for a higher note (*sursum*), denotes only a moderately higher note, combinations like *cm* and *tm* stand for moderately quick and moderately slow notes, respectively. Indeed, as Smits van Waesberghe (1942b: 653) demonstrated, the letters *c*, *cm*, *tm* and *t* (and probably also *cb* and *tb* as extremes) determine a continuum of durations,



albeit that the combinations *cb*, *cm*, *tm* and *tb* are rather infrequent. Sometimes, but also rarely, only the letter *m* is used to denote a duration shorter than *t* but longer than *c*. In these cases, Smits van Waesberghe continues, *m* often replaces *cm* or *tm*. Hence, Aribó's description, in which three-note lengths occur, indicated by *c*, *m* and *t*, appears correct, with the proviso that short- and long-note lengths have measured proportional durations, whereas *cm*, *m* and *tm* may denote in-between or flexible durations. Probably, these latter durations are also mentioned in Guido of Arezzo's *Micrologus* (early eleventh century). Describing how to compose grateful melodic lines, Chapter XV of this famous treatise states:

It is also necessary to beat the melody as though by metrical feet and to hold some notes twice as long or twice as short as others, or to have a *tremula*, that is, a tone duration [tenor] of varying length ([Kohlhaas 2001: 155](#)).

Statistical Analyses

Given the abovementioned findings and observations, I conducted some research on the relationship between several note-length and text variables. This study was performed by using four randomly selected introit antiphons from the 1974 version of the *Graduale Romanum*: (i) *Misereris omnium Domine*, (ii) *Rorate caeli desuper*, (iii) *Puer natus est nobis*, (iv) *Nos autem gloriari oportet*².

These introits were melodically corrected by consulting the manuscripts Beneventum VI 34; St. Yrieix 903; and Albi 776 (see the [Appendix](#)), as well as Smits van Waesberghe's ([1942b](#); [1947](#)) exposition of the *litterae significativae* in the notation of St. Gall. It suffices here to say that nearly all corrections are in agreement with the restitutions in the *Graduale Novum de Dominicis et Festis* (2011). Moreover, the neumes of the four introits, comprising 457 notes, of which 411 refer to neumes for multisyllabic words, were studied by comparing the manuscripts, Einsiedeln 121 and Laon 239, to make clear, based on distinctions made by Cardine, which individual notes are short and which are long. In the few cases that Einsiedeln and Laon did not agree, Bamberg-lit. 6 was consulted. We used introit chants, and not, for instance, graduals, believing that, whatever relationship may exist between text and music, this relationship may be particularly strong in introits (and probably also in communions). Graduals, for instance, were often composed formulaically (centonisation), a technique that seems likely to preclude a close relationship of music and text ([Hoppin 1978: 69](#)).

Fixed Note Values and Ratios

For reasons that will become clear later, the research presented in this article was executed by paying attention only to the 411 notes on which the multisyllabic words (162 syllables) are sung. To each of these notes, several values were attached that represent particular durations. Starting with mensuralist assumptions, Cardine's ([1970](#)) distinction between (relatively) short and long notes was followed by attributing the value 1 to short and the value 2 to long notes. We opted for this dichotomy, and not, for instance, for the note values proposed by Wagner ([1912: 395](#)), because of our previous demonstration, based on a comparison of the *Cantatorium* of St. Gall (SG 359; see the [Appendix](#)) with Laon 239, that Cardine's rhythmical interpretations (in terms of long and short) of the various neumatic signs are nearly always correct ([Van Kampen 1993](#)). Because the pes quadratus in Cardine's dichotomy corresponds to the value of two normal syllabic beats, the virga and tractulus were given the value 2 for a long note. The only, but rare, exception is when these signs are represented in Laon 239 by *puncti*: in that case, the value 1 was applied. These attributions agree with the usual mensuralist interpretation (see, for example, [Murray 1963](#)), albeit that such fixed values are clearly at variance with Cardine's semiology. The endnotes of liquescent neumes, like the *epiphonus* and *cephalicus*, were also given the value 1. Following Cardine ([1959](#); [1961](#)), notes immediately preceding an expressive neumatic break were considered to be long notes, and thus the value 2 was attributed. The note before a *quilisma* was also believed to be a note of 2 beats (see [Apel 1958: 115](#)). Finally, the letters *c* and *t* in Einsiedeln 121 and *a* in Laon 239 were assumed to influence the rhythm of chant in such a way that the letter *c* appended to a long note would make that note short, and the letters *t* or *a* appended to a short note would make that note long. Because of their inconsistent application in different manuscripts (see above), we did not follow Smits van Waesberghe's ([1960](#)) suggestion that the letters *c* and *t* have rhythmic consequences when the letter *c* is appended to a short, or *t* to a long note.

Besides the ratio 1:2, other ratios were applied to get measured note values. These ratios ranged from 1:1, via 1:1.2, 1:1.4, 1:1.6, and so on, up to 1:3 inclusive. Although not in themselves of interest, these ratios were selected because they were felt to be potentially helpful in tracking down the reason that mensuralists are so much interested in the ratio 1:2. We will address this issue further later.



After having established the various note values for a particular ratio, these values were added for each neume separately. The resultant sum-scores were termed the *mensuralist note-duration sum-scores* or, in short, D scores. Hence, 11 series of D scores exist, which refer to the variables $D_{1:1}$, $D_{1:1.2}$, $D_{1:1.4}$, etc. In addition, *contextual note-duration sum-scores* (CD) were determined, which means that, for each particular syllable, the value of D is expressed as a percentage of the sum of the D scores for all the syllables of the word of which the syllable forms part.

The eleven CD variables, though based on measured note values, were calculated in agreement with the semiological view of Agustoni and Göschl (1987: 23). According to this view, the ultimate source from which Gregorian melodies rise is the word of the Holy Scripture. It is claimed by these authors that the sacred word lives ‘in vollkommener Symbiose mit seiner Veredelung, der Melodie’. Similar ideas were expressed by Cattin (1984: 69, 76), though Cattin admits that sometimes exceptions to this rule may be noted, thus demonstrating a less than perfect relationship. Of course, the emphasis laid on the inseparable unity of the text and the melody does not mean that the separate syllables are unimportant. One has to realise, however, that the influence of a particular syllable on the chant’s rhythm must always be understood in the light of how the remaining syllables of the word affect the rhythm. Thus, while fully admitting the importance of the syllables, the mutual relationships between the syllables of a word are particularly emphasised. It is for that reason that contextual (that is, relative) note-duration sum-scores were calculated. If the above-stated contentions of Agustoni and Göschl (1987) and Cattin (1984) hold, the CD scores cannot only be expected to correlate with the relative length of the syllables, but also to surpass the correlations between D and these length-scores.

As will be explained later, it is important to note that the Pearson product-moment correlations among both the 11 D and the 11 CD variables are very substantial⁹. Even the rhythmically most divergent variables, that is the D and CD variables for the ratios 1:1 and 1:3, turn out to have correlation coefficients of 0.77 and 0.81, respectively, whereas the highest correlation among two D or CD variables is 0.999 (all p values <0.01 ; $n=162$).

Semiologically Inspired CD Values

Besides the above-mentioned D and CD scores that are based on measured note values, similar scores, but now related to the variables D_L and CD_L were derived in an attempt to represent the semiological view. While still rejecting the theory of a text-analogous rhythm in the case of neumes of more than one note, we tried to represent this view as closely as possible by measuring the widths of the neumes in Hakkennes’ (1984) *Graduale Lagal* (using photocopies in an enlargement of 141%). The resultant D_L scores here were also transformed into CD_L scores, calculated in the same way as mentioned above. High correlations of, respectively, 0.88 and 0.90 ($n=160$; $p<0.01$) and beyond were found between the semiologically inspired D_L and CD_L scores, on the one hand, and the mensuralist D and CD scores, on the other. This is, of course, not surprising as both kinds of sum-scores are largely dependent on the same number of individual notes.

Text Variables

With the various note-duration sum-scores and contextual note-duration sum-scores thus far distinguished, several variables exist that lend themselves to the investigation of their relationship with variables related to, or derived from the text. Nine text variables were introduced to examine this relationship:

- T_1 : A score of 1 (vs. 0) was assigned, if the syllable carries the principal accent.
- T_2 : A score of 1 (vs. 0) was assigned, if the syllable directly precedes the accented syllable.
- T_3 : A score of 1 (vs. 0) was provided, if the syllable is the first one in a multisyllabic word.
- T_4 : A score of 1 (vs. 0) was assigned, if the syllable is the final one in a multisyllabic word.



- T_5 : A score of 1 (vs. 0) was assigned, if the syllable is positioned between the principal accented syllable and the last syllable.
- T_6 : The 'sa-analogical' length of the syllable (see later) as measured in milliseconds.
- T_7 : The length of the text syllable expressed as a percentage of the time needed to pronounce the entire word of which the syllable forms part. Note that, T_7 relates to T_6 in the same manner as the CD variables to the ones that represent D.
- T_8 : A score of 1 (vs. 0) was assigned, if the syllable has the highest T_6 score of the syllables of a word.
- T_9 : A score of 1 (vs. 0) was provided, if the syllable has the lowest T_6 score of the syllables of a word.

A principal components analysis of the nine text variables ($n=106$) resulted in the identification of three varimax-rotated, that is, zero-correlated dimensions. The two most important factors, with high loadings of, respectively, T_6 (0.83) and T_7 (0.83) on the first dimension, and T_1 (0.84) and T_3 (0.83) on the second one, were interpreted as speech duration and accentuation. The third factor proved only characterised by T_2 (-0.91).

T_6 was originally measured by analysing the audio-recorded texts of the four introit antiphons by means of a computer program developed at the Department of Experimental Audiology at the Vrije Universiteit in Amsterdam. However, as the syllables in the graphics produced by this program could not be properly distinguished, due to the mixing of sounds between adjacent syllables (see [Van Kampen 1994](#)), the texts were re-recorded with the original syllables replaced by the syllable 'sa' (pronounced with the 's' and 'a' of, for instance, the Latin word, sapiens), but maintaining the original speech rhythm. Because the sa-analogical representation of the text resulted in a sound graph, in which the boundaries between the syllables are clearly visible (see [Fig. 1](#)), the syllables' duration, with the exception of 22 syllables, which are followed by a pause at the end of a sentence or clause, could be easily determined. Moreover, a correlation of 0.84 ($p<0.01$) was observed between the original time estimations and the later obtained T_6 values, despite the fact that different speakers were involved in both analyses.

Text and Neume Duration

[Table 1](#) presents the Pearson-product moment correlations between the nine text variables, on the one hand, and the scores on several D and CD variables, inclusive of D_L and CD_L , on the other hand. Because the correlations among the mensuralist D and CD variables proved to be rather high, despite differences in the ratio between short and long durations (see above), only the correlations calculated for the ratios 1:1, 1:2, and 1:3 are listed. The correlations with T_1 to T_5 are based on 160–162 observations; those with T_6 on 138–140 observations, and the correlations with T_7 , T_8 and T_9 on 104–106 cases.

It is clear from [Table 1](#) that the correlations of the nine text variables with the CD and CD_L variables are nearly always stronger than the correlations with the scores on D and D_L . Similar results emerged with respect to the correlations not mentioned in [Table 1](#). However, only T_1 and T_7 are really important in this respect, because these text variables are the only ones that correlate rather substantially with the CD and CD_L variables.

When it comes to the interpretation of the higher correlations with the contextual note-duration sum-scores, we may first note that these correlations converge with the emphasis placed by Agustoni and Göschl ([1987](#)) and Cattin ([1984](#)) on the (sacred) word as the ultimate factor through which the syllables exert their influence. This notion appears all the more supported, if account is taken of the almost zero correlations between T_6 and the various D scores. However, also realising that the squared correlations between T_7 and the CD scores reveal only modest levels of shared variance, Cattin's ([1984](#)) description of a less-than-perfect relationship between text and melody (see above) appears superior.



Figure 1. The sa-analogical representation of the first ten syllables of the introit *Misereris omnium Domine*. 

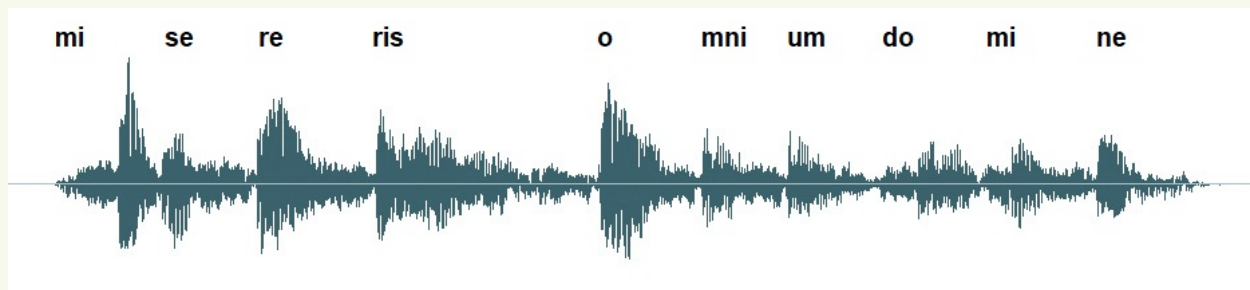


Table 1. D and CD variables and their correlations with several text features

	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉
D _{1:1}	0.42 ²	-0.14	0.32 ²	-0.27 ²	-0.05	0.04	0.11	-0.11	0.11
CD _{1:1}	0.58 ²	-0.22 ²	0.47 ²	-0.24 ²	-0.19 ¹	0.15	0.43 ²	-0.11	0.26 ²
D _{1:2}	0.38 ²	-0.19 ¹	0.22 ²	-0.19 ¹	-0.06	0.06	0.16	-0.05	0.12
CD _{1:2}	0.56 ²	-0.31 ²	0.38 ²	-0.14	-0.21 ²	0.19 ¹	0.54 ²	-0.01	0.25 ¹
D _{1:3}	0.32 ²	-0.20 ²	0.15	-0.13	-0.07	0.07	0.17	-0.01	0.11
CD _{1:3}	0.49 ²	-0.34 ²	0.29 ²	-0.06	-0.20 ²	0.21 ¹	0.56 ²	0.05	0.22 ¹
D _L	0.36 ²	-0.20 ¹	0.19 ¹	-0.14	-0.06	0.10	0.21 ¹	-0.01	0.07
CD _L	0.53 ²	-0.30 ²	0.34 ²	-0.10	-0.22 ²	0.22 ¹	0.52 ²	0.02	0.17

¹: $p < .05$ ²: $p < .01$

T₁ and Neume Duration

No specific predictions were formulated in respect of the Pearson correlations between the various contextual note-duration sum-scores and T₁. Nevertheless, the actual correlations listed in [Table 1](#), which imply that accented syllables compared with the remaining syllables of a word are often sung on neumes of longer duration, cannot be considered to be completely unexpected because it is known from Cardine's (1970) research that isolated notes, which carry the letter *t* or an episema are typically found to be associated with the syllable with the principal accent (see above). So, the correlations between T₁ and the various CD measures obviously confirm Cardine's observations, albeit now for neumes that consist of more than one note.

Of course, the conclusions thus far obtained remain valid whether the text variables are correlated with the mensuralist CD variables or with CD_L. Nevertheless, we must emphasise once more that the semiologically inspired D_L and CD_L variables have no other meaning than being imprecise measures of the mensuralist D and CD variables. Hence, the correlations in [Table 1](#) with D_L and CD_L do not lead to an alternative class of interpretations that are supportive of Cardine's (1970) semiology.

T₇ and Neume Duration

Given the relatively strong correlations between the CD variables and T₇, several conclusions may be drawn. The most obvious interpretation is, of course, that the relative length of the syllables is rather directly reflected in the relative lengths of the neumes. However, other inferences are also possible, particularly when one realises that the scores on the mensuralist CD variables show a number of different outcomes. With respect to CD_{1:2}, for instance, the scores were found to range from 8.70 to 84.60%. Hence, it seems almost certain that nuanced durations, which are here related to T₇, must also exist in the case of neumes of merely one note. So, instead of adjudging a fixed duration of two beats to an isolated virga, tractulus or uncinus, as was proposed, for instance, by Murray (1963) (see above), it transpires that these notes, in agreement with Cardine's (1970) semiology, show flexible durations that conform



to the relative lengths of the syllables. We address this topic further later. Here, we only dwell on the fact that our conclusion that the mensuralist representation of the chant's rhythm obviously leads to the recognition that isolated notes have non-fixed durations is in complete agreement with the above-mentioned distinction in medieval treatises between *metrum* and *rhythmus*. The emphasis in these treatises lies mostly on what distinguishes the two concepts. Nevertheless, it also seems understandable why some treatises assert that all metre is rhythm, but not all rhythm is metre. Indeed, both manifestations refer to the same function, namely to provide an adequate rhythmical representation of the text, but only the *metrum* handles different feet of strictly measured duration (though, in this context, not necessarily according to the ratio 1:2).

Multiple Correlations

Besides individual correlations of the text variables with the CD scores, it is also possible to calculate multiple correlations. This makes sense, particularly because the correlation between the most relevant text variables, T_1 and T_7 , is almost zero ($r=0.05$; NS; $n=106$). So, higher (multiple) correlations may be expected than the correlations thus far considered. To calculate these correlations, we first decided to execute multiple regression analyses⁴ in which all nine text variables were simultaneously entered as predictors of the contextual note-duration sum-scores. These analyses were followed by a second series of analyses, in which only the text variables T_1 , T_7 and T_9 were entered as predictors, because only these variables proved to be selected in each analysis, when using the forward method to yield the most appropriate regression equation. The multiple correlations will be denoted R in the first, and R_{179} in the second series. All analyses were carried out under listwise deletion of data, using a sample of 106 cases when examining the 11 mensuralist CD variables, and a sample of 104 cases when examining CD_L .

The principal aim in conducting these analyses concerns the possibility of comparing the multiple correlations in relation to different ratios. As indicated above, if the ratio 1:2 is really important, the highest multiple correlations may be expected when the scores on CD are based on that ratio. Nevertheless, strong discrepancies among the multiple correlations cannot be expected, as the various CD variables were found to correlate substantially (see above).

Support for the Ratio 1:2

[Table 2](#) shows the multiple correlations for the various CD variables, each time based on a particular ratio. The R and R_{179} values for the variable CD_L are also listed.

Although the differences in [Table 2](#) in each of the two series of multiple correlations are indeed very small, the values show a very interesting pattern. Starting with the CD variable for the ratio 1:1, and subsequently investigating the CD scores for the remaining ratios, it can be seen that R and R_{179} first increase in value, attain a maximum value for the ratio 1:2, and then decrease until the ratio 1:3 is reached. These findings are in full agreement with the mensuralist view that neumes typically consist of short notes of one beat or long notes of two beats or combinations of both (albeit that, in the present context, no information is provided about the length of isolated notes; but see later). Moreover, it is with the ratio 1:2 that the rhythmic arrangements of the syllables within the context of a particular word attain their strongest relationship with the rhythmic arrangements of the neumes. The reason, however, that notes of one beat and notes of two beats are sometimes selected remains obscure: we could only demonstrate, in a series of independent-sample t-tests, that neumes with a greater number of notes (whether short or long) often include fewer notes of two beats ($p<0.001$), and the same was found for neumes which represent syllables that are the first one of a multisyllabic word (T_3) ($p<0.05$). It is also of interest that the lengths of the neumes are not always proportionally affected by the rhythm of the text. Indeed, the squared value of R_{179} for the ratio 1:2 demonstrates that only about 62% of the total variance is explained by the model.



Table 2. Multiple correlations for CD variables that rely on different ratios

CD	R	R ₁₇₉
CD _{1:1}	0.759	0.723
CD _{1:1.2}	0.777	0.747
CD _{1:1.4}	0.791	0.765
CD _{1:1.6}	0.799	0.777
CD _{1:1.8}	0.803	0.784
CD _{1:2}	0.804	0.787
CD _{1:2.2}	0.802	0.786
CD _{1:2.4}	0.799	0.784
CD _{1:2.6}	0.793	0.779
CD _{1:2.8}	0.787	0.773
CD _{1:3}	0.780	0.766
CD _L	0.741	0.717

Flexible Durations with Neumes of One Note

In the above, the inference was drawn that isolated notes display the same nuanced durations as the text syllables on which these notes are sung. It might be interesting, therefore, to recalculate the multiple correlations between the text variables T_1 , T_7 and T_9 , on the one hand, and $CD_{1:2}$ on the other hand, but this time also paying attention to the flexible durations of isolated notes. However, an important preliminary question is whether these notes have flexible note values of two beats on average, or that these durations refer to lengths that circle around a lower mean, given that the full gamut of note lengths is indicated by the letters *cb*, *c*, *cm*, *m*, *tm*, *t* and *tb* (see above).

In support of the first answer, it can be said that isolated notes, both in the St. Gall manuscripts and in Laon 239, are nearly always represented by a virga, tractulus or uncinus, that is, by signs that last two beats in neumes of more than one note. However, according to Cardine (1985: 41), the full range of note values, from the smallest to the largest, can be classified as lying between one and two, ‘ohne dabei die seinerzeit gegen den Mensuralismus vorgebrachten Einwände aus den Augen zu verlieren’.

For chants composed in syllabic style, Cardine’s vision is undoubtedly correct: in these chants there is no reason to depart from the actual lengths of the syllables while singing the notes. The same applies when, say, three or more isolated notes in the context of otherwise non-syllabic chants or passages immediately succeed each other. However, for single isolated notes in that context, the situation might be different because the remaining neumes of the chant are normally characterised by durations that equal at least two beats. Regarding the ratio 1:2, for instance, the neumes of more than one note have note-duration sum-scores that vary from 2 to 11, with a mean value of 4.75 and a standard deviation of 2.09. It seems a little bit unnatural, then, to suppose that isolated notes in a non-syllabic context last less than two beats on average.

This issue was investigated by introducing a slightly modified $CD_{1:2}$ variable, referred to as $CD_{1:2/M}$, for which the scores were calculated on the basis of note-duration sum-scores ($D_{1:2/M}$) in which the value 2, if applied to a single isolated virga, tractulus or uncinus, was replaced by 1.5, the value associated with the letter *m*. Such a replacement fits Cardine’s (1985) assertion that the full range of note values has a middle value represented by *m*, and contrasts with the mensuralist idea that isolated notes usually are long and thus must be given the value 2. In 50 out of 54 cases of isolated notes, the value 2 had to be replaced by 1.5. The remaining 4 isolated notes retained their original $D_{1:2}$ score of 1 because they were represented by puncti in Laon 239. The $CD_{1:2/M}$ scores that, mostly because of these replacements, had to be calculated refer to 110 text syllables that form part of 37 multisyllabic words. Therefore, the variables $CD_{1:2}$ and $CD_{1:2/M}$ have 52 of the 162 scores in common.



Examining the scores on $CD_{1.2/M}$ by means of multiple regression analysis, with only the text variables T_1 , T_7 and T_9 as predictors, the multiple correlation ($R_{179/M}$) proved to be 0.751 ($n=106$). Because this value is lower than the one observed for $CD_{1.2}$ ($R_{179}=0.787$), it is clear that isolated notes in a non-syllabic context have note values that do not vary around m , but equal the value 2 on average. Also here, $CD_{1.2}$ and $CD_{1.2/M}$ are highly correlated ($r=0.99$; $p<0.01$), resulting in rather small differences between R_{179} and $R_{179/M}$. Again, however, large differences cannot be expected, as the note-duration sum-scores, which led to the calculation of the scores on $CD_{1.2}$ and $CD_{1.2/M}$, primarily reflect the same number of notes. Moreover, as the scores on $CD_{1.2}$ and $CD_{1.2/M}$ are even identical in 52 out of 162 cases, this also increases their correlation.

Durations of Single Isolated Notes in Non-syllabic Chants

Having established now that isolated notes in the context of non-syllabically composed chants last two beats on average, it might be interesting to know what level the multiple correlation would reach when account is taken with the actual durations of these notes. Given the rather strong relationship thus far observed between the relative lengths of the syllables and the relative lengths of the neumes, we may, of course, anticipate the emergence of a higher value (denoted by $R_{179/V}$), compared with R_{179} .

To estimate the actual duration values for single isolated notes, we hypothesised that these note lengths, which on average are characterised by two beats (and thus by the letter t), must occupy positions on Smits van Waesberghe's (1942b) continuum of duration values (see above) that range from m as a lower bound to tb as an upper bound. With m and t representing the values 1.5 and 2 respectively, tb may indicate a value of 2.5.

The distribution of T_6 seems roughly in agreement with these inferences. As T_6 follows a nearly symmetrical, but non-normal (Shapiro-Wilk test, $p<0.05$), distribution with a mean of 0.50, and a minimum and a maximum score of 0.19 and 1.01 respectively, simply adding the value 1.5 to T_6 results in a new variable, T_{6TR} , that has exactly the same distribution as T_6 , but now with a mean of 2 and a lowest and a highest score of 1.69 and 2.51 respectively. These three values are not far removed from the above-mentioned values, 2 for t , 1.5 for m , and 2.5 for tb . Only the value for m might be a little too high, but, as it is known (see above) that m is sometimes used when tm is meant, the difference becomes acceptable. Hence, the T_{6TR} scores may at least be approximately similar to the actual durations of single isolated notes. Also knowing that the letter c stands for durations of one beat, we may further infer that cb usually represents the value 0.5 on the above-mentioned continuum. So, compared with the durations of isolated notes in syllabically composed chants, which range from roughly 1 (c) to 2 (t) and have a mean of 1.5 (m), the durations of single isolated notes are likely to circle around the value 2 (t) and have a range extending from about 1.5 (m) to 2.5 (tb). It transpires, therefore, that isolated notes in syllabically composed chants must be performed in a somewhat quicker tempo than single isolated notes.

Of the above-mentioned 50 isolated notes with $D_{1.2/M}$ scores of 1.5, 39 were given a new note-duration score ($D_{1.2/V}$) that equalled the value obtained for T_{6TR} . For the 11 isolated notes that remain, no such alternative scores could be provided, as these isolated notes were followed by a pause at the end of a sentence or clause, making the derivation of the scores on T_6 and T_{6TR} impossible. Taking account of the 39 T_{6TR} values, and the still unchanged $D_{1.2}$ scores for neumes of more than one note, a new series of contextual note-duration sum-scores was established, this time representing the variable $CD_{1.2/V}$. The variables $CD_{1.2/V}$ and $CD_{1.2}$, which correlate 0.99 ($p<0.01$), have 41 out of 135 scores in common and $CD_{1.2/V}$ and $CD_{1.2/M}$ having a correlation of 0.98 ($p<0.01$), have 42 out of 135 scores.

Examining the scores on $CD_{1.2/V}$ by means of multiple regression analysis with the text variables T_1 , T_7 and T_9 as predictors, the multiple correlation ($R_{179/V}$) proved to be 0.790 ($n=106$). Since this value is higher than the one observed for $CD_{1.2}$ ($R_{179}=0.787$), the above-stated expectation that the multiple correlation would show a higher value, when account is taken of the actual durations of isolated notes in otherwise non-syllabically composed chants, is clearly fulfilled.

No Additional Shortenings or Lengthenings

In the analyses thus far, the assumption was followed that the letters c and t and the episema in the notation of St. Gall and the letters c , t and a in Laon 239 do not imply any extra shortening or lengthening of an already short or long note forming part of a neume of two



Table 3. Five CD variables for the ratio 1:2 and their relationship with the text variables T_1 , T_7 and T_9

	$CD_{1:2}$	$CD_{1:2M}$	$CD_{1:2N}$	$CD_{1:2CT}$	$CD_{1:2N/CT}$
T_1, T_7 and T_9	0.79 ²	0.75 ²	0.79 ²	0.78 ²	0.78 ²
T_1	0.56 ²	0.57 ²	0.48 ²	0.56 ²	0.49 ²
T_7	0.54 ²	0.47 ²	0.57 ²	0.52 ²	0.56 ²
T_9	0.25 ¹	0.26 ²	0.20 ¹	0.21 ¹	0.16

¹: $p < .05$ ²: $p < .01$

or more notes. Given the highly inconsistent use of these letters and episema, when comparing the four introit chants in the codices of Einsiedeln 121 and Laon 239, this assumption seems almost by definition correct. Nevertheless, to investigate this issue further, two additional contextual note-duration sum-score variables $CD_{1:2CT}$ and $CD_{1:2N/CT}$ were introduced. Again, these variables were examined by means of multiple regression analysis for their relationship with the text variables, T_1 , T_7 and T_9 .

The dependent variable $CD_{1:2CT}$ was based on a new series of note-duration sum-scores in which the original $D_{1:2}$ scores, assuming that a short note with *c* asks for extra shortening, and a long note with *t* (or *a* or the episema) for extra lengthening, were transformed into $D_{1:2CT}$ scores, thereby substituting the value 1 for *c* by the value 0.5 for *cb*, and the value 2 for *t* (and *a* and the episema) by the value 2.5 for *tb*.

A similar procedure was followed with respect to $CD_{1:2N/CT}$ but, to derive the scores on that variable, $D_{1:2N}$ was selected instead of $D_{1:2}$ to provide the initial note-duration sum-scores that had to be adapted. Once more, the newly derived variables and the original ones turned out to be strongly related, with a correlation of 0.99 between the variables $CD_{1:2CT}$ and $CD_{1:2}$, and a correlation of 0.99 between the variables $CD_{1:2N/CT}$ and $CD_{1:2N}$ ($p < 0.01$). Moreover, the variables $CD_{1:2CT}$ and $CD_{1:2}$ were found to have 72 of their 162 scores in common and the variables $CD_{1:2N/CT}$ and $CD_{1:2N}$ had 59 of 135 scores in common.

The multiple correlations, $R_{179/CT}$ in the case of $CD_{1:2CT}$ and $R_{179N/CT}$ in the case of $CD_{1:2N/CT}$ turned out to be 0.777 and 0.782, respectively. As these values are lower than the multiple correlations in the case of $CD_{1:2}$ and $CD_{1:2N}$ respectively, the letters *c* and *t* and the episema in the notation of St. Gall and the letters *c*, *t* and *a* in Laon 239 cannot be said to indicate an extra shortening or lengthening of an already short or long note that forms part of a neume of at least two notes. So, apart from the situation that long notes with *c* and short notes with *t* count for short notes and long notes respectively, the use of these letters is indeed superfluous.

With the establishment that the variables $CD_{1:2CT}$ and $CD_{1:2N/CT}$ do not lead to further increases in the multiple correlation with T_1 , T_7 and T_9 , we fall back on the dependent variable $CD_{1:2N}$ because this variable now appears the one to be most strongly related to the three text variables (see also [Table 3](#)).

The conclusion, therefore, is inevitable that the characteristics which define $CD_{1:2N}$ offer the most dependable description of the rhythm of Gregorian chant. As such, there are three ways in which the chant's rhythm parallels the rhythm of the sacred words (see also [Van Kampen 2012](#)):

1. in neumes of one note in syllabically-composed melodies the parallelism is realised by a direct transmission of the lengths of the syllables to the lengths of the notes. In most cases, the note values range from 1 (*c*) to 2 (*t*) beats and have a mean of 1.5 (*m*) beats;
2. in neumes of one note in non-syllabically-composed chants this is done by transmitting the note lengths which relate to the syllables' lengths in a slightly slower tempo. The note values now usually range from 1.5 (*m*) to 2.5 (*tb*) beats and have a mean of 2 (*t*) beats;
3. in neumes of two or more notes the parallelism is warranted by adjusting the neume lengths to the relative lengths of the syllables by inserting a greater or smaller number of notes, some being short and lasting one beat (*c*), and others being long and lasting two beats (*t*).



Some exceptions to rule 3 are nevertheless likely. This applies, for instance, to the *initium debile* note of a *pes* or *torculus specialis*, which may last only 0.5 beats, the value corresponding with the letter combination *cb*. Moreover, in the case of liquescent signs, it also appears established that no fixed duration values are applied. In this respect, Cardine (1963) is certainly right in his attempts to refute mensuralism. Finally, it must be emphasised that the rhythm of Gregorian chant is, like the rhythm of all music, dependent on other features, such as the slowing down of the tempo at the end of a musical sentence, as, for instance, described in the *Commemoratio Brevis* (see Wagner 1912: 360), or the fact that the chant's modal structure summons particular accentuations, which may modify to some extent the length of the notes. Basically, however, the above-mentioned rules for neumes of one note and for neumes of more than one note are the ones that characterise the rhythm of Gregorian chant.

Historical Authenticity

It goes without saying that the empirical findings presented in this article have particular consequences if we consider historical authenticity as an essential aspect of performing Gregorian chant (see also Mahrt 2000). Historical authenticity aligns with a manner of singing that is fully in line with the performance practice of the ninth century because the reported findings support the distinction between the ninth-century concepts of *rhythmus* and *metrum*, which were specifically intended to describe the rhythm of chant in that time. Hence it seems possible to restore, on the basis of the ninth-century information available to us, a historically authentic performance practice that corresponds with the way of singing just after the period when the music was created⁵. Thus, instead of adhering to the widely accepted view of Agustoni and Göschl (1987: 24) that a *bivirga* (or another neume) which is appended to an accented syllable must be sung in a slower tempo than the same neume on a pre-tonic syllable, our statistical analyses indicate that the composer's choice for a particular neume already conforms to the text rhythm, namely by taking care that the neume lengths parallel the relative lengths of the syllables, which is accomplished by inserting a greater or smaller number of notes, or by making some notes twice as long as others.

To illustrate what it means to sing Gregorian chant in a historically authentic manner, Fig. 2 shows the score of the gradual *Angelis suis*, as it is reproduced in the *Graduale Novum* of 2011, together with the neumes in the notation of St. Gall. However, based on that latter notation, square notes that belong to a neume of more than one note are marked by a horizontal episema, if at least referring to long notes of two beats, whereas no episemata are added if short notes of one beat occur. Whether or not to insert an episema rests on Cardine's (1970) dichotomy of long versus short notes and on a study by Van Kampen (1993) about neume notation in the Cantatorium of St. Gall. No episemata are applied to notes that belong to neumes of only one note, as these notes are characterised by nuanced durations that are dependent on the lengths of the accompanying syllables. These notes may either show a mean of 2 beats in non-syllabically-composed chants or a mean of 1.5 beats in syllabically-composed melodies.

To further illustrate the above-mentioned insights, Audio Sample 2 offers a specially made mechanical recording of the gradual *Angelis suis*. This recording is intended to show how the melody proceeds if the appropriate duration values are strictly followed. Of course, sung by a choir, the recording would be different to a certain degree, but for illustrative purposes the mechanical recording might be preferred.

Melodic Peaks

Though particularly dependent on T_7 , $CD_{1.2V}$ also correlates with T_1 (see Table 3), the text variable which refers to the presence of an accented syllable. It is known, however, that accented syllables usually also coincide with melodic peaks (Reese 1940: 166). Introducing the variable *H* in the present data set to indicate whether a syllable is accompanied by a neume with at least one note having the highest pitch per word, the observations by Reese could be supported: *H* and T_1 turn out to have a correlation coefficient of 0.54 ($p < 0.01$; $n = 160$). Hence, also in this respect, text and melody in Gregorian chant appear to be clearly related.



Figure 2. The gradual *Angelis suis*. 

Grad.
II.

A N-GE-LIS su- is mandá- vit de te,

ut custódi- ant te

in ómni-bus vi- is tu- is.

¶ In má-ni-bus portá- bunt

te, ne un- quam offén- das ad lá-

pi-dem pedem tu- um.



ENDNOTES

1. For some readers, the very mentioning here of mensuralist theories might be surprising. Most modern books about Gregorian chant only deal with semiology, so the former controversy about the true rhythm of chant now seems to have been settled in favour of Cardine's semiology. Also, avoiding any and every form of mensuralism is often now considered a hallmark for correctly singing Gregorian chant. Noting, however, that early manuscripts from different countries often strongly agree about which notes are long and which are short, it seems hard to believe that only nuanced note lengths would characterise the rhythm of chant. Moreover, the idea that Gregorian chant could have been passed on through oral tradition for centuries without some way to measure the length of the notes sounds incredible. So, reopening the mensuralist case appears timely and may even be profitable.
2. Though randomly selected, the four introit antiphons may not be representative of the entire population of introits. Hence the possibility that the results obtained in this paper are in some way influenced by the particular selection of introit chants cannot be completely ruled out.
3. Throughout the paper, many correlations are reported. The Pearson product-moment correlation (r) measures the strength and direction of a linear relationship between two variables, X and Y . The formula to calculate the correlation coefficient returns a value that is always between $+1$ and -1 , where $+1$ indicates a perfect positive, and -1 a perfect negative relation, whereas the value zero indicates no association at all. To visualise the strength of the relationship, one may square the value of r , because the resultant coefficient of determination indicates the proportion of the total variance that X and Y have in common. Thus, a correlation of 0.40 indicates that 16% of the total variance is shared, and a correlation of 0.80 indicates that 64% of the total variance is shared.
4. The general purpose of multiple regression is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable. For example, educational researchers might want to understand whether exam performance (Y) can be predicted based on test anxiety (X_1) and lecture attendance (X_2). The predicted value of Y is a linear transformation of the X variables such that the sum of squared deviations of the observed and predicted Y is minimised. With X_1 and X_2 , the prediction of Y is expressed by the equation $Y = c + b_1X_1 + b_2X_2$, in which c is a constant and b_1 and b_2 are the regression weights of the predictor variables. The correlation between predicted Y and observed Y is called the multiple correlation (R). Squaring this correlation, one knows the proportion of variance explained by the independent variables.
5. Of course, there are some serious problems left, mainly related to vocalisation ([Smits van Waesberghe 1938](#)) and the execution of ornamental neumes, like the quilisma and oriscus (see, e.g., [Wiesli 1966](#); [McGie 1996](#)).

APPENDIX: MANUSCRIPTS REFERENCED

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3. Beneventum VI–34: Codex VI–34 of the Congress Library of Benevento, *Gradual* (11th–12th century). *Paléographie Musicale*, first series, XV.
4. Saint-Yrieix 903: Codex 903 of the National Library of Paris. *Gradual of Saint-Yrieix* (11th century). *Paléographie Musicale*, first series, XIII.
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ABSTRACT

The principal aim of this paper is to investigate the rhythm of Gregorian chant as it was performed prior to the eleventh century. Discussing the two main approaches, semiology and mensuralism, that have been followed since the beginning of the twentieth century to unravel the mysteries associated with the chant's rhythm, several hypotheses were formulated, which were further examined by conducting statistical research on the relationship between several note-length and text variables, which were measured in four randomly selected introit chants. The results proved to be partly in agreement with mensuralist theories and partly with semiology, thereby also corroborating the distinction between the ninth century concepts of *rhythmus* and *metrum*.

Keywords. Gregorian chant, note values, rhythm, *rhythmus*, *metrum*, mensuralism, semiology

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