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The Rhythm of the Scribe

A Serial Analysis of the Density of Writing in the Gospels of Henry the Lion

Abstract: In all medieval manuscripts, the width of a line is subject to continuous variation. This is true even of the most sumptuous volumes, entrusted only to the finest of scribes. The Gospel of Henry the Lion, produced by the monk Herimann in the second half of the 12th century, is one such case. In order to determine whether these variations were involuntary or intentional it is necessary to measure them and, in particular, to apply methods developed for the analysis of time series. In this way, cyclical fluctuations can be identified, along with other fluctuations, non-cyclical but systematic, which prove that such oscillations in the writing are not merely evidence of a faltering hand, but rather an expression of consummate artistry and skill.

Henry the Lion's Gospels were probably written in around 1175 at the monastery of Helmarshausen, in Saxony, by a Benedictine monk named Herimann (Fig. 1–2)[1].

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I would like to extend my gratitude to Marilena Maniaci and Ezio Ornato, thanks to whom this article came to be translated into French, not without a few linguistic conundrums. I also extend my gratitude to Alain Guerreau, who was willing to proofread and correct the final draft. [Note of the editor: a full digital reproduction of the codex is now available on the library's website (http://diglib.hab.de/?db=mss&list=ms&id=105-noviss-2f)].

1 For a considerable time, the manuscript was dated to 1175; see Jansen 1933, and Kruger 1972. This dating was contested by Reiner Haussherr, 1980, 3–15, and the codex was subsequently post-dated to around 1188 on the basis of a consecrational inscription on the Altar of Our Lady at Brunswick in Lower Saxony. Even though art historians (as well as an increasing number of historians) adhere to the dating proposed by Haussherr, the older dating has once again begun to find favour, thanks to some new details discovered in the dedication of a second altar to Our Lady located in the crypt of the cathedral of Brunswick, and some new arguments of a palaeographical nature. In actual fact, this question cannot be answered in a definitive way. The most recent and wide-reaching approach

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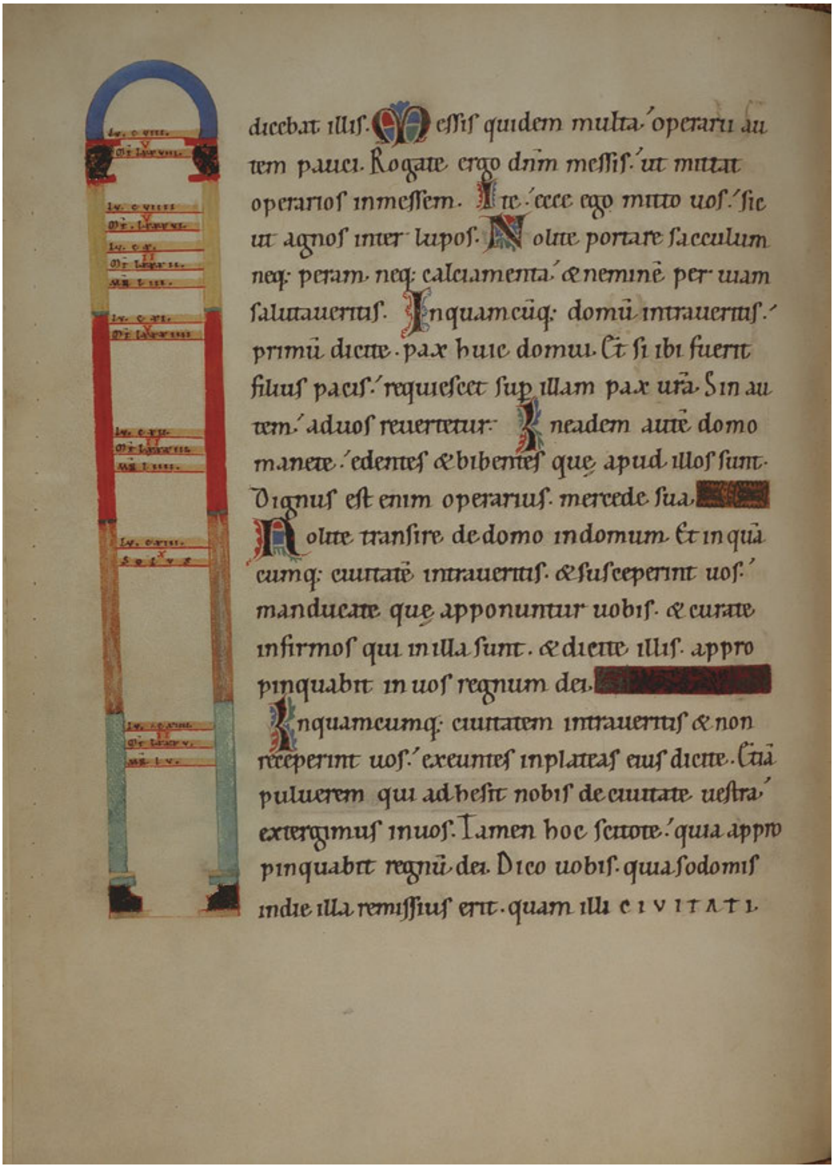

Fig. 1: The Gospel of Henry the Lion, produced by the monk Herimann in the second half of the 12th century, f. 136v © Herzog August Bibliothek Wolfenbüttel

to Herimann's work (which includes a complete bibliography) can be found in Kötzsche 1989. See also Möhle 1991, 1–24.

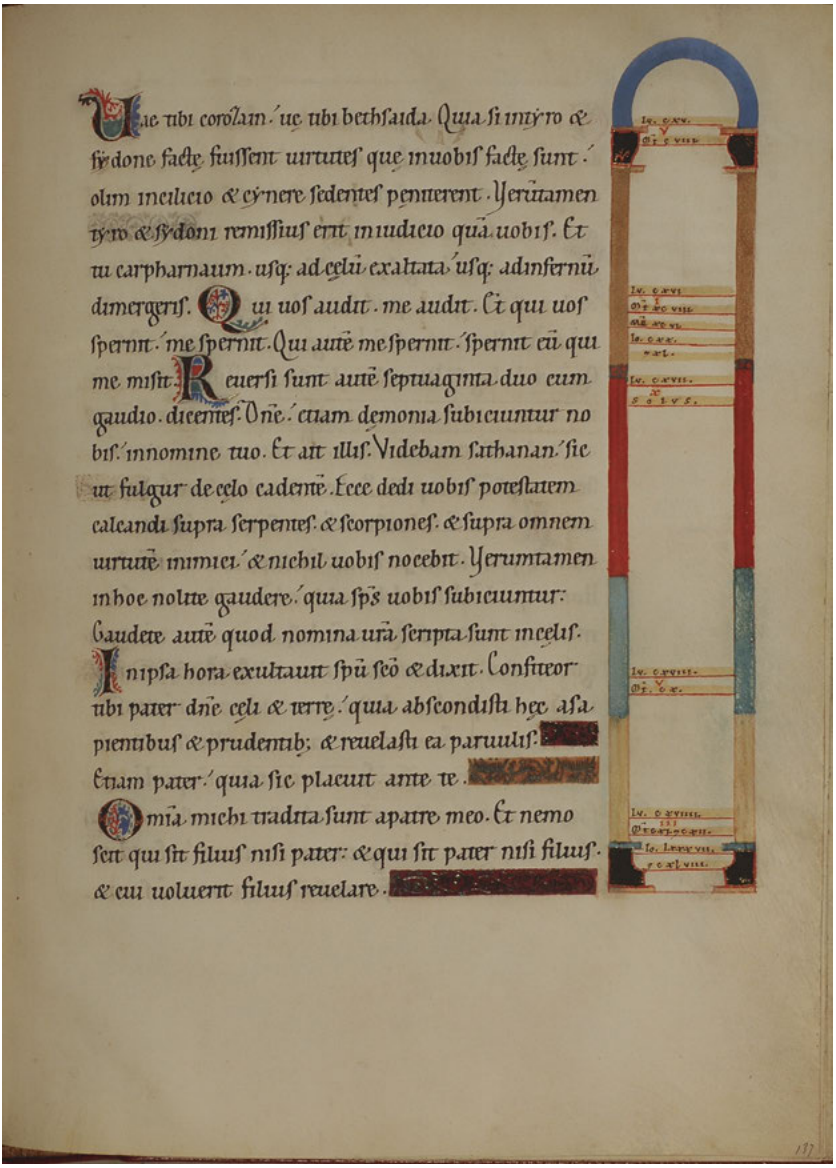

Fig. 2: The Gospel of Henry the Lion, produced by the monk Herimann in the second half of the 12th century, f. 137r © Herzog August Bibliothek Wolfenbüttel

In his analysis of the sumptuously executed manuscript, Peter Rück has shown that the monk was very attentive to the smallest details and that he adopted a highly varied repertoire of scripts in order to achieve the desired objective: for the main text body he employed the Carolingian minuscule, whilst he used a 'spaced out script' for the *capitula* and the *Comes*, as well as for the dedication in chrysography, where he identified himself alongside his illustrious commissioning patron. Similarly, in the display scripts, Herimann introduced a number of variants that are different in size, colour and form. As Peter Rück confirms[2], Herimann was an expert who was able to create in the Guelf Duke's Gospels a veritable *Museum graphicum* of the Romanesque era.

It is therefore undeniable that the monk of Helmarshausen was in all ways a master of his art. For this reason, it is all the more surprising to observe fluctuations in the script that repeatedly manifest themselves throughout the Gospels. Thus, one immediately notices that at the beginning of quire 19, in the Gospel according to St. Luke, Herimanns's script is far more compressed than on the preceding page—indeed, whilst in the manuscript one counts an average of 38 characters per full line (excluding, that is, lines which contain decorated initials, title lines, and sequences of spaced out script), f. 136v holds two lines less than the average and f. 137r two and a half more. The difference is similarly large between quires 21 and 22: on f. 160v Herimann puts down 723 characters of normal script, as opposed to 803 on the following page (f. 161r). The difference is only a question of four characters per line, so one can reasonably suppose that such a disparity is of no significance in the overall concept envisaged for the book. In actual fact, this is not so. The approximate size of these fluctuations can be gauged when one considers the transcription in Carolingian minuscule of the Gospel according to St. Luke which occupies ff. 114v to 166v[3], for a total of 105 pages composed of 22 lines.[4] If the scribe had written the text with the space-consuming minuscule seen on f. 136v, his transcription would have occupied 111 pages, whereas had he used the 'economical' script seen on f. 137r, 97 pages would have sufficed. The difference is almost equivalent to the length of a quire composed of four bifolia. Extended to the entire volume—here, by including blank pages or illustrated pages, one attains a total of 226 leaves assembled into 31 quires—we reach a total of

2 Rück 1989, 122–154.

3 One encounters a change of quire on ff. 113, 121, 129, 137, 145, 153 and 161.

4 F. 121 contains 21 lines, whilst f. 166 contains 18.

about 50 pages, equating to three quires.[5] The spacing out or compression of the script therefore becomes highly significant, given that, at the very least, this will have an impact on the thickness of the volume and the amount of parchment used to manufacture it.

Herimann—who completed the text of the Gospels and the *Capitulare Evangeliorum*[6] prior to the first part of the manuscript up to the Canon Tables or the purple-tinted page of the Gospel according to St. Matthew[7]—was clearly obliged to modify the density of his writing. In the examples cited, modification of the script was carried out at the meeting point between two quires, and this phenomenon can only be explained if the copyist decided in advance to contain one part or the other of the text within a pre-established number of pages. Now, were it indeed the case that a calculation was made in advance, the scribe would necessarily have had to ensure from time to time that he was not straying too far from the fixed norm, and he would have done so by regulating the density of his writing accordingly. Therefore, the change observed on ff. 136v–137r is simply the visible result of this periodic and ongoing checking and adjustment procedure.

It would be interesting to follow Herimann's writing line-by-line in order to identify the variation in the rhythms it contains. Unfortunately, simple visual observation will not provide us with reliable results, since the eye can only discern the most conspicuous oscillations. The smallest fluctuations tend to escape our notice, all the more so when an assessment is subject to distraction by other elements of the tracing and the *mise en page*, namely the use of spaced out script (so as to make the *nomina sacra* stand out, in association with display capitals or a space filler inserted at the end of a section), and the decoration of text, either by means of ornamental bands placed at the beginning of a *breve* or a weekday pericope, or by ornamental initials and line endings used in the transcription of a Eusebian section[8], or—in the case of initials—to function as verse identifiers.[9]

5 Most of the quires in the manuscript are quaternions. The dimensions of the leaves (34.2 × 25.6 cm) lead one to suppose that the realisation of each quaternion required the skins of two calves. See Bischoff 1991, 87.144, above all 113ff.

6 This is a calendar (also known as the *Comes*) that sets out the order of Mass readings throughout the liturgical year.

7 This practice is entirely typical in the realisation of the Gospels. See Bischoff 1994.

8 The *breves* and Eusebian sections are subdivisions in the Gospels. In the Gospels of Henry the Lion, the Gospel according to St. Luke is divided by 21 *breves* and 343 Eusebian sections.

9 From this point on, we shall employ the terms 'highlighted line' or 'ornamental band' for all lines written in gold ink on a coloured background placed at the beginning of the *breves*. The line endings which in general close a Eusebian section consist of coloured and gilded bands

1 Measurement of writing density

Writing density can be measured by means of a counting operation. To achieve this aim, it will suffice to count the words[10] or characters contained within a sufficiently extended space. At first glance, this operation does not raise any significant problems; however, in reality it is not as simple as it seems. In fact, the shorter the text, the greater the influence of variation factors: words might be relatively long, and the random presence of very long or very short words may distort results. The counting of characters—which unquestionably constitutes a less inaccurate evaluation method—also presents some problematic issues: characters are not all of the same width; so much so, in fact, that a particularly high frequency of wide letters—such as *m* or *u*—necessarily reduces the number of characters per space unit on account of the script being more spaced out. The difficulty arises owing to the irregular distribution of word length or of letter width: if one were to select portions of text of sufficient length so as to render the variations in these parameters effectively negligible, the results would be practically free of errors and the two methods would be equivalent.

We must now ask what length of text must be analysed in Latin Gospels if one wishes to obtain an error-free result. By considering the case of a printed text—where disparities can only be due to variations in the frequency of letters—one can affirm that a passage of text is sufficiently long when a completely different passage containing the same number of characters occupies the same space. One can therefore allow that in all the passages analysed the frequency of the appearance of letters will be more or less the same. In practice, however, this definition of 'sufficient length' is rather problematical, as a test carried out on some printed passages of script reveals. In a recent edition of Petrarch's *De viris illustribus*, Ezio Ornato,[11] after having measured twenty samples numbering one thousand characters in length, obtained a coefficient of variation of 1.45%. This is a low but not null value, and in any case, even if one is prepared to accept the margin of error, the area covered by one thousand characters in Henry the Lion's

intended to fill spaces devoid of script. For the relevant terminology (in French), see Muzerelle 1985.

10 A word count was performed by Frenz 1976, 347–375, on some pontifical documents dating from the Late Middle Ages. The count was carried out by tallying up all the words contained in three lines of text. As we shall see, this method is adequate for the purpose of conducting a rough survey of writing density based on average values, but is not sufficient to support research into a scribe's writing rhythm.

11 Ornato 1975, 198–234.

Gospels corresponds to 1.2 pages.[12] We are therefore very far from being able to track Herimann's writing line-by-line.

Another solution could be envisaged, namely that of taking into account the typology of letters, so as to know not only the number of letters per line, but also the frequency of each letter. By weighting the latter according to the average width of the corresponding letter, one can tell, line-by-line, whether the copyist's writing is compressed or spaced out. In order to apply this method, one would certainly require more time than Herimann needed to carry out his transcription. The method might be rigorous, but is totally impractical in terms of the number of researcher-hours that would be necessary for its practical application.

On the other hand, it does not take very long to compare the margin of error in the first two methods—word count and character count—with the results of the third method on a small portion of text. To this end, from a selection of five pages of the volume (33v, 91r, 136v, 137r, 179v), a sample of 23 lines was put together. If one takes the ligatures *nt* and *et* into account, as well as the spaces between words, one can amass almost a thousand measurements. The use of a photographic enlargement made it possible to measure not only the spaces between words, but also the spaces between the individual letters within words. An example, line 15 of f. 137r, provides a helpful illustration of the measuring method employed (Fig. 3).

Fig. 3: Spaces between the individual letters within words, f. 137r, line 15.

This method is far from perfect. Indeed, a certain number of symbols, such as punctuation marks, were not accounted for, and capital letters (not represented in Chart 1) were grouped together, without worrying about their nature or their form. In

12 Clearly, the method applied by Ezio Ornato is not well suited to manuscript writing, owing to the fact that the width of each printed character is consistent by definition, hence the method cannot take into account the variations of density in the writing. If, in any of the 41 consecutive pages of the Gospel according to St. Luke, the relationship between the number of characters and the length of the line always remains the same at approximately +/- 1 % of the mean (on average 34,255 letters distributed over 127m of lines, according to the results obtained—which are presented in the Appendix—by dividing the page into five sections), one can deduce that all the letter widths have a similar frequency, but one cannot establish the respective share of the writing density and of the typology of the characters in determining their width, and likewise one cannot ascertain the rate of occurrence of each character.

addition, variations in the way in which letters were drawn in relation to the density of the writing (the problem as regards the proportion of letters will not be addressed in the next part of the study) were not taken into account, nor were variations owing to the position of the initial or final letter in a word.[13] The boundary between two adjacent letters was determined by guesswork because, in certain cases, the termination of a letter can overlap on to the letter that follows. Finally, it proved difficult to measure the space between two words, and sometimes it is not easy to confirm that the copyist really intended to separate them. These limitations notwithstanding, the results obtained can nevertheless represent an acceptable approximation of the width of minuscule characters.

To trace an *m*, Herimann required, on average, almost three times more space than he needed to trace an *i* (2.9:1). All the other letters of the alphabet fall within the two extremes, including the ligatures *et* and *nt*, as well as the blank spaces between words. If one arranges the letters in ascending order based on width, one observes a very clear gap between the *e* and the *a*, which separate the letters with only one descender from those which include multiple descenders and those with bowls. This gap is particularly interesting, since the average width of characters—weighted according to their respective frequency—falls exactly between the *e* and the *a*.[14] The relationship between the two letters, shown in Chart 1, represents the averages, whose standard deviations reflect the variations in the density of Herimann's script. It should be noted that some fluctuations also affect the relationships themselves: thus, the relationship between the letters *n* and *b* with the other letters is relatively stable, whereas the differences are more significant in the case of rare letters such as *x*, or of letters of relatively simple form, such as *l* or *s*.

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13 Without dwelling too much on this aspect, it should nonetheless be pointed out that the notion of a letter's 'typical' width is a rather slippery one. Letters exhibit different 'behaviours' depending on the situation/environment in which they are found. This is the case with the letter *s*, which slants towards the right when the succeeding letter is lacking ascenders but is held back from a letter that includes a bowl situated on the left (i.e. *d, g* and *q*; see, likewise, in Chart 1, the difference between these letters and the aforementioned characteristics when the bowl is situated on the right, i.e. *b* and *p*). These differences cannot be taken into account in a simple calculation of the width of each letter. However, it is equally true that some constants exist that are independent of the environment in which the letter is found: a minuscule *m* will *always* be broader than an *a*, and an *a* will *always* be broader than an *i*, regardless of the situation with respect to these letters. These conditions having been specified, the results presented in Chart 1 should be considered an 'estimate' of the theoretical determination of the width of each letter.

14 Regarding the frequency of each letter, see Tab. 2. The value of 1.47 takes into account the blank spaces between words, capitals and abbreviations such as *us* and *que*, for which the corresponding symbols are found on the line of writing. If one dismisses all these elements, the value increases to 1.53 (compared with 1.50, a value obtained for the printed text of Plutarch).

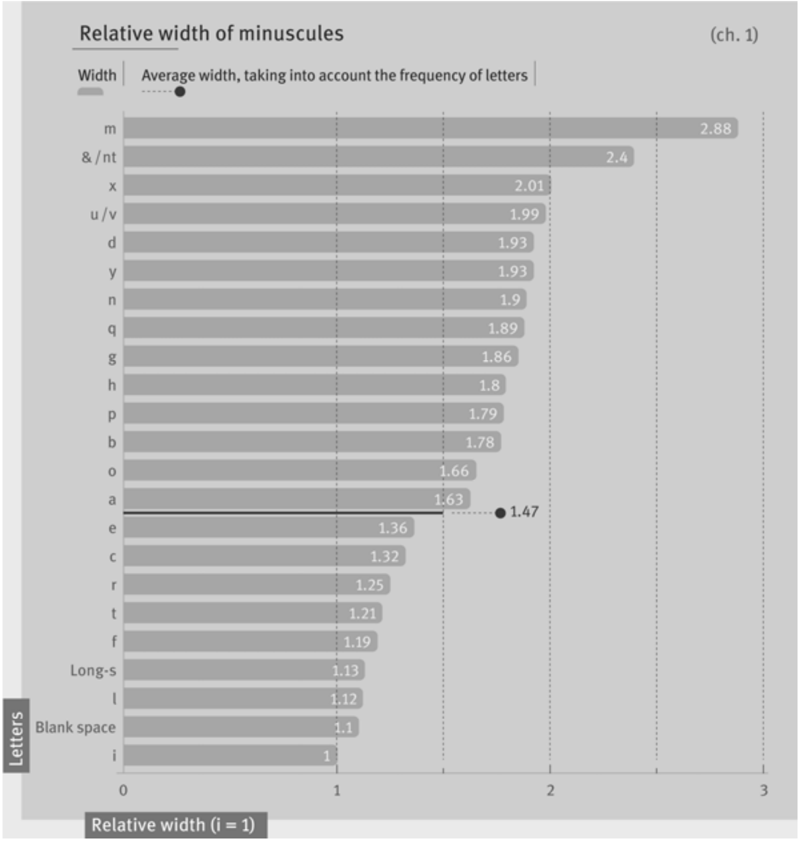

Chart 1: Relative width of minuscules

Calculation of the average width of each letter is necessary so as to be able to determine the influence (i.e. weight) it has on the calculation of the overall width of the writing. Accordingly, all the letters[15] were counted line-by-line in a length of text extending for four pages (ff. 136r–137v), and the size of each was multiplied by its weight. Essentially, since all the widths are expressed in terms of their relationship with the letter *i*, the operation consisted in calculating, for each line, the number of 'average' *i*'s that each contained. Since the lines are not always completely occupied by script, this number was related to the length of the written portion and

15 This calculation takes into account the blank spaces between words and ligatures, as well as the abbreviations *us* and *que*, but does not include ornamental initials.

expressed in the form of a percentage.[16] The resulting value hereinafter in our study will be referred to as the *standardised letter width*; if its value is under 100, this signifies that the line contains a greater number of *i*'s than a line containing an 'average number of *i*'s', and therefore that the script is narrower than the average observed in the book taken as a whole.

A second series of measurements was carried out, this time consisting in a simple character count. This furnished the *average letter width*[17] and, based on the same principle, the *average word width* forms a third series.[18] A few examples suffice to illustrate the difference between the standardised width and the average width of the letters: in the case of line 18 of f. 136v, the first parameter has a value of 102.7 (the script here is a little more compressed than it is on the rest of the page; see Tab. 1), whilst the second parameter has a value of 93.4. The difference is due to the unusually high frequency of narrow letters, namely nine *e*'s, six *i*'s, five *t*'s, and four *s*'s. Line 20 of f. 137 exhibits the opposite phenomenon (95.8 as opposed to 102.7), this time thanks to numerous appearances of the letter *m*.

Average writing density per page depending on the various measuring methods employed (tab. 1)

Page	Width of the standardised letter		Width of the average letter		Width of the average word	
136r	106.1	(2.5)	106.0	(6.7)	106.1	(23.7)
136v	105.4	(2.7)	105.0	(6.7)	110.2	(18.6)
137r	93.9	(3.8)	92.9	(5.0)	91.7	(13.1)
137v	95.0	(4.3)	96.3	(7.1)	92.2	(14.2)

Standard deviation shown in brackets

Tab. 1: Average writing density per page depending on the various measuring methods employed

16 In the calculation to establish the density of the script ϑ in a line composed of a group α of letters (where α represents all the letters of the alphabet, including the special forms mentioned in the previous footnote), the following formula is applied:

$$\vartheta = l|\Sigma\,(\alpha \times weight_{\alpha}),$$

where l = the length of a line, and *weight* = the relative width of the letter in accordance with Chart 1.

17 This calculation does not consider blank spaces, nor the abbreviations *us* and *que*.

18 In the calculation, we assigned a value of 0.5 to words split at the end of a line.

Compared with the two other methods, measurement of the standardised width of letters reduces the fluctuations in script density: the averages and the deviations demonstrate that this procedure tends to 'flatten out' fluctuations caused by variations in the frequency of letters and eliminates the frequently abnormal imbalances which result from calculating the average length of words. However, the standardised width is very sensitive to abrupt variations in script density occurring between one line and another, as seen in the example of f. 137r—whilst almost everywhere else the writing density is under 100, on line 19 Herimann suddenly spaced out his writing, a manoeuvre which has an immediate impact on the standardised width value (105.9).

The evaluation of the error probability inherent to the three methods presupposes that one of them produces optimal results, or at least results that are better than those obtained using the other two. For this reason, from now on we shall allow that the standardised width of the letters better reflects the real situation. In addition, we shall allow that, in the passage analysed for this test (87 lines,[19] corresponding to more than 600 words or about 3,300 letters) the three methods in question produce identical results, which amounts to saying that, in a sample of 87 lines of a Latin Gospel book, all the letters and all the word lengths crop up with the same frequency. In the strictest sense, this postulate is probably false; however, the deviation compared to what is observed in reality is quite small, as borne witness to by Petrarch's *De viris illustribus*,[20] in which the average frequency of letters—despite its being a completely different text—is nearly the same as in the 87 lines of the Gospel book analysed here (see Tab. 2). Thus, at least where the standardised width and the average width of letters are concerned, we can confirm that the samples composed of 87 lines produce similar results.[21]

Based on these two hypotheses, we can now calculate experimentally the maximum and average deviations of each of the two approximations (calculated by grouping the lines in successive order; i.e. 1, 2, 3... 87) in relation to the standardised width of letters. This was considered the best method to employ. The results are presented in Chart 2.

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19 The decorated band on f. 136r does not affect the calculation.

20 Ornato 1975, 224.

21 The averages shown in Table 1 are all orientated equally in this direction.

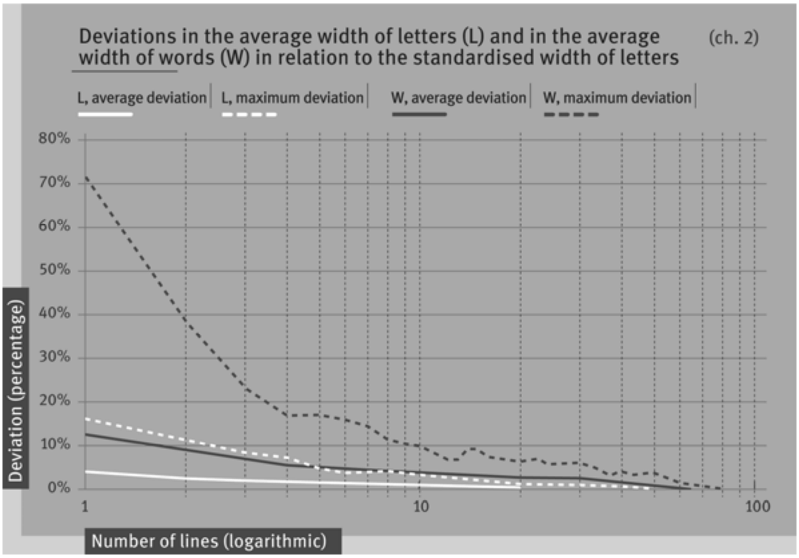

Chart 2: Deviations in the average width of letters (L) and in the average width of words (W) in relation to the standardised width of letters

Not surprisingly, the method that adopts the average width of words is the one which produces the least satisfactory results. If one considers a deviation of 10% as the maximum acceptable, one would need to work with samples made up of ten lines in order to be sure of never exceeding that value. Regarding the average deviation, it is roughly 4%.[22] By using the average width of letters, samples composed of two and a half lines, which is to say roughly one hundred letters, would be sufficient, with an average deviation of a little more than 2%. For samples composed of four lines, the average deviation obtained by applying this method is 1.8% and the maximum deviation does not exceed 7%. Consequently, in accordance with the degree of accuracy deemed acceptable, measurement of writing density in a manuscript would not call for more than 100–200 letters.

22 This means that in 78 samples made up of ten lines of consecutive text, one encounters at least one case where the average width of letters deviates at least 10% from the standardised width. In these samples, the average difference between the two values is roughly 4%.

Frequency of letters, ff. 136r–137v (tab. 2)

Letters	Total number of occurences	Ff. 136–137, as an percentage	Frequency in Petrarch, in percentage
a	232	7.8	7.51
b	41	1.25	1.67
c	118	360	3.74
d	124	3.79	2.69
e	375	11.45	11.18
f	20	0.61	0.85
g	24	0.73	1.27
h	29	0.89	0.59
i	449	13.71	11.95
l	116	3.54	3.32
m	138	4.21	5.83
n	199	6.08	6.04
0	155	4.73	5.28
p	88	2.69	2.78
q	54	1.65	1.60
r	160	4.89	6.88
s	259	7.91	7.81
t	292	8.92	8.32
u/v	329	10.05	10.16
x	24	0.73	
y	5	0.15	
z	1	0.03	
&/nt	43	1.31	
Others			0.54
Total	3275	100	100.00

In addition, on ff. 136r-–137v, the following appear:

Abbreviations (b; and q;)	10
Capital letters (without decorated initials)	60
Blank spaces	586

Tab. 2: Frequency of letters, ff. 136r–137v

2 Writing density in the Gospel according to St. Luke

Taking these results into account, the measurement of writing density was carried out based on the average width of letters. Each page of the Gospel according to St. Luke (ff. 114v–166r)[23] was subdivided into five sections: three composed of four lines (sections 1, 4 and 5), and two composed of five lines (sections 2 and 3), so that the deviation in relation to the standardised width of the letters never exceeds 7% and remains on average under 2%. For each of the sections identified thus, all the letters were counted prior to measuring the overall amount of space that they take up on the line.[24]

The average width of the constituent letters, calculated on the basis of approximately 86,800 characters, representing a total length of almost 320 m, measures 3.7 mm. This global figure is quite imprecise when one considers Herimann's writing density, which shows considerable fluctuations across the 520 sections of text surveyed. The disparity between the two extremes is roughly 30%, and these extremes can occur between adjacent folios, pages or single sections of text. Within 'very dense' passages of text one might well encounter a 'very spaced out' section, whilst elsewhere one might find alternating passages of spaced out and densely packed script which, when plotted on a graph, translate into a series of peaks and troughs. If one excludes some partially identifiable trends, Herimann's script seems to be the product of pure whimsy.

23 ff. 107r–110r contain the *Capitula* and the Prefaces to the Gospel according to St. Luke; ff. 110v–113r are dedicated to the iconographic scheme; f. 113v is the page that carries the text's initial; f. 114r is a chrysographed page set out on a coloured background; f. 166v constitutes the last page, three quarters of which is blank. From now on, all these pages will be excluded from the calculations.

24 The blank spaces between words and the ';' that shortens the endings *us* and *que* were not included in the calculation; the capitals and ligatures *nt* and *st* were made compatible by representing them by means of a unique symbol; the illuminated lines, decorated bands, ornamental letters and passages of spaced out script were also subtracted from the length of the line. The average line length calculated in this way is therefore shorter (14 cm) than that put down during the *mise en page* (15 cm). It can be seen that Herimann utilised 7% of the page for decorative elements and graphic devices aimed at drawing attention to certain parts of the text. The role played by decorative elements is even more important in the Gospel according to St. Matthew (see Rück 1989, 127).

2.1 Methods employed in serial analysis

By applying the methods used in time series analysis, we are now going to see if we can confirm that, contrary to one's initial impression, Herimann's writing does in fact contain some cyclical trends. Such analytical methods, developed by experts in econometrics, are aimed at disclosing the existence of regular rhythms in a non-lacunar series of data organised chronologically and at regular intervals. This makes it possible to account for such rhythms and enables one to make some projections.[25]

In a time series, economic statistics distinguishes three basic elements: the trend, which describes long-term behaviour; cyclical components, which act on a series at regular intervals; and 'white noise', which does not present any regularity and cannot be accounted for by systematic factors, given that it depends on random occurrences. These different elements can be linked to one another by addition or multiplication, or exponentially, although one normally begins by presuming the existence of an additive link. Thus, according to the simplified model, each value measured at moment *t* is the result of the sum of the trend (g), the cyclical components (c) and white noise:

$$\vartheta y_t = g_t + \Sigma\,(cl_{t\ldots}\,cn_t) + \Sigma_t$$

25 Over the last twenty years, time series analysis has attracted considerable interest. The new methods—autoregressive and spectral analysis procedures in particular—were developed and applied in historical studies, above all in the reconstruction of economic conditions and the history of prices. Concerning these matters, see the special issue of *Histoire et Mesure* dedicated to time series (6, 1–2 [1991]), or the contributions of Stier (14,1 [1989]), Spree (Supplement 4 [1991]), Metz / Stier (17, 3 [1992]) and Thome (17, 3 [1992]) in the latest issues of *Historische Sozialforschung (Quantum)*. During the course of this investigation, we will not be employing the more complex methods which have recently been the subject of a good amount of discussion. Rather, we shall employ the more straightforward and descriptive methods used in classical time series analysis; these are well known to historians who practice statistical analysis and are adequately explained in widely available manuals on statistical economics. Given that this article addresses an area where the application of such methods is not commonplace, we shall mark out the boundaries in order to briefly outline the fundamentals of classical time series analysis. Details of the calculation procedures will not be furnished here; the interested reader will be able to find directions to such information in the footnotes. To this, one can usefully add the very clear introduction to classical time series analysis presented in Esenwein-Rothe 1976, (principally vol. 2), and Leiner 1982.

The validity of this formula implies that at any moment it should be possible to isolate and quantify the various factors contributing to the influence.

The extrapolation of postulates from the time series analysis of a medieval scribe's writing rhythm presents some problems and can only be contemplated when a certain number of precautions are taken. For this reason, in the Gospels copied by Herimann, we can say nothing about the time factor, which is of critical importance in statistical economics—indeed, we have no idea how much time would have been required for the scribe to perform his task, nor the speed at which he would have worked. Instead of a series of chronologically ordered moments in time, we have a series of sections of adjacent text, and we can only measure the density of the transcription in the latter. In addition, it is impossible for us to know whether text density was influenced by time-related factors: for example, whether the scribe's writing pace changed between the beginning and end of the day, after many hours of painstaking labour.

Also doubtful is the way in which the various components of the series are linked to one another. The choice of an additive model in the presentation that follows is motivated by the fact that a reduction in writing density does not lead to strong fluctuations in the series and that, furthermore, elimination of the cyclical component by means of the multiplicative model does not reduce its variance by much.[26]

Finally, the analysis of a medieval scribe's working method presents some problems that the classic set of tools offered by time series analysis are of little help in tackling. Indeed, time series analysis can only identify regular cyclical variations: non-periodic fluctuations, which also depend on arrhythmic factors, cannot be disclosed by using the simple method, and likewise it is impossible to separate two non-periodic superimposed movements.

At first blush, the notion that Herimann may have adjusted the rhythm of his writing for some reason other than that of simply meeting incidental needs and instead *a fortiori* according to a mathematical model can only seem mistaken (as indeed it is, if one interprets the term 'model' in its strictest sense), and the idea that the spacing out of a line of script was the result of a trend, a cyclical and a random component might seem absurd. It is not, though, when one construes measurements in hundredths of a millimetre as an expression of the tendency of the scribe to space out or compress his writing in specific places. The scribe's hand does not obey a model; the model only serves to expose some underlying tendencies.

26 The comparison recommended by Thome 1992, 75ff. between the script density averages and the standard deviation (for this test, all the values were calculated on the basis of half quires and page-by-page) also supports an additive model, because the standard deviation values do not change in accordance with the writing density averages (which, indeed, are plotted parallel to the abscissa axis).

3 The trend

Calculation of the trend is generally based on the application of two methodologies: moving averages and polynomial fitting. The moving averages can be well adapted to the data, but they necessarily entail some losses at the beginning and end of the series (which can, however, be restored by means of an estimate). Given that, in the case at hand, the data loss would have been too noticeable[27], it was deemed preferable to use two polynomial functions capable of estimating the values of y (writing density) based on the values on the x axis, which is to say those of the 520 sections of measured text. In these functions, the sum of the deviations between the estimated values and the real values is nil and that of quadratic deviations minimal.

In a time series, the accuracy of the estimation depends on the degree of the polynomial, progressing from the regression line (first degree equation) to the quadratic polynomial (second degree equation), to the cubic polynomial (third degree equation), and so on. Given that the cycles which lasted up to the length of a quire (= 8 leaves = 16 pages = 80 sections) should not be eliminated by the quadratic equation, each polynomial that would have created a peak and a trough within a single quire had to be disqualified.

Some other considerations are critical when choosing the degree of the polynomial. In theory, in a series of data, one should select the polynomial whose variation is very clearly lower than that of the preceding one, but on the other hand only little higher than the polynomial of the succeeding degree. It is important, moreover, that the polynomial should closely fit the raw data on the visual level. For ff. 114v–136v, these two criteria are fulfilled by a polynomial equation of fourth degree;[28] for ff. 137r–166r, they are fulfilled by the polynomial of the fifth degree.[29]

27 The estimate for data lost at the two extremes is subject to error, and in my opinion the parameters are difficult to determine. For this reason, priority has been given to functions, all the more so because the extrapolation of a function above and beyond the available data would be pointless. In the spheres of econometry and economic history, weighted moving averages are often employed to smooth out time series.

28 The function, rounded to twelve decimal points, is as follows: $g^t = 3{,}522329049613 + 0{,}006301805498\,t - 0{,}000145832749\,t^2 + 0{,}000001198808\,t^3 - 0{,}000000002897\,t^4$, for a t interval of 1–225. The variance that results after subtracting the trend, which is to say the value of the polynomial for each ascending degree of the same, is equivalent to 68,2 % (regression line), 61 % (second degree), 59,2 % (third degree), 55,6 % (forth degree), 55,5 % (fifth degree), 53,8 % (sixth degree), 51,4% (seventh degree), 49,8% (eighth degree), 49,4% (ninth degree)… 46,6 % (thirteenth degree).

29 Trend function: $g^t = 373445558919 + 0{,}017692166694t - 0{,}000351741975t^2 + 0{,}000002978540\,t^3 - 0{,}000000010997t^4 + 0{,}000000000015t^5$. The residual variance decreases in the following way: 93.0% (regression line), 91.8% (second degree), 91.1% (third degree), 91.0% (forth degree), However, excessive initial and final values represent a major disadvantage of all polynomial fittings; this can be observed above all in the second part of the series (see Chart 3).

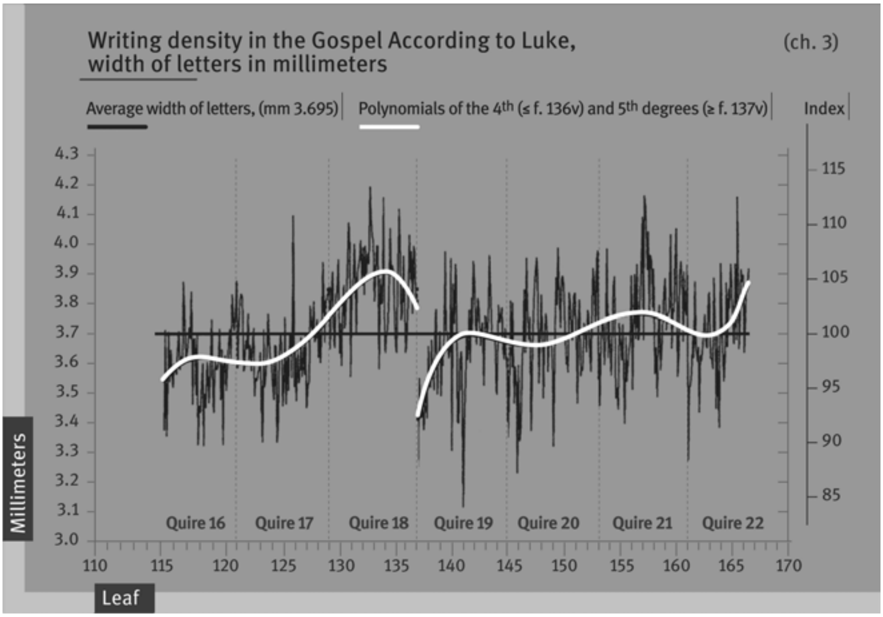

Chart 3: Writing density in the Gospel According to Luke, width of letters in millimeters

Splitting a time series for trend determination is uncommon and introduces risks of error, especially when subsequent analyses are performed using the recombined series. This pitfall notwithstanding, it is undeniable that in this case such an approach is not lacking a sound basis. To be sure, apart from a few fluctuations in the upper parts of quire 17, Herimann's writing seems gradually to become more spaced out; we would scarcely have needed a mathematical equation to create a well-fitted curve to reflect this phenomenon. However, this trend terminates rather abruptly at the end of f. 136v. Starting from the next page, Herimann increases the density of his writing considerably, and then gradually reduces it again, but it never becomes as spaced out as that seen in quire 18.

86.2% (fifth degree), 86.1% (sixth degree), 85% (seventh degree), 84.6% (eighth degree), 83.1% (ninth degree)… 80.9 % (thirteenth degree).

The decision to divide the series in two was not suggested solely by the sudden variation in writing density, which can also be observed between quires 21 and 22, but above all on account of the fact that, between quires 19 and 22, Herimann managed his writing in a different way. The variation cycles are not as long: Herimann adjusts the density of his writing much more frequently, which gives the impression of a veritable to-ing and fro-ing between compressed and spaced out script. This explains why, contrary to what happens in quires 16 to 18, in the succeeding quires the polynomial modification is not much more effective in representing the appearance of the series than the simple calculation of the average.

The visual impression can be reinforced by some figures. Thus, in the first part of the series, an average width of 3.70 mm corresponds to a standard deviation of 0.183; in the second, an average of 3.69 mm corresponds to a standard deviation of 0.177, which is very close to the previous one. However, when the trend is subtracted the deviation decreases to 0.136 in the first case, whereas in the second it barely changes (0.165), although as an absolute value it clearly remains higher than in the previous quires.[30] Respectively, the reductions in the standard deviation are 26% (quires 16 to 18) and 7% (quires 19 to 22). The portion located between quires 16 to 18 is also influenced by a very long-lasting trend which is not seen in the successive portion.

All this takes place, then, as if the copyist, having completed quire 18, noticed that the density of his writing was too low and decided to check his work more often. This is not the case in a short passage in quire 21, where once again we see a script which is just as spaced out as in quire 18. It is possible that Herimann wanted to make certain parts of the text coincide with the end of a quire. In fact, quire 10 terminates with the last verse of the Gospel according to St. Matthew; the end of quire 15 contains the first pages of the iconographic programme of the Gospel according to St. Luke, which commences at the beginning of the following quire with a portrait of the evangelist. In this perspective, it is obvious that if Herimann wanted to avoid blank pages just as much as 'widows and orphans', he would have had to have undertaken a very closely managed regulation of the space occupied by his transcription by adjusting the density of his writing. To be sure, he could have adopted other tactics as well, such as abbreviations, which in any event play a role in the Gospel according to St. Luke, even if their frequency does not exceed 2.5%.[31]

Furthermore, some other factors can exert an influence on script density. Consequently, one can see that quire 18—where the writing is at its widest—is relatively

30 Even the polynomials tested up to the thirteenth degree show little variation. See the data in the previous footnote concerning the residual variance.

31 To calculate the abbreviation rate, the number of letters counted on ff. 113v–166v were placed in relation to the corresponding number of letters contained in the Vulgate (90/910). See Berger 1893.

poor in ornamental elements (see Chart 4). This tendency for there to be a negative correlation between writing width and an abundance of ornamentation manifests itself in quires 16 to 18, where it looks as though Herimann compressed his writing so as to create space, in the text, for a considerable number of decorative elements. The hypothesis that an abundance of ornamentation might be linked to an increase in writing density should, however, be qualified; when a scribe ends a line at the end of a Eusebian section, the writing may well be expansive. In quire 20, where Herimann was very sparing with decorative elements, one does not see any spacing out of his writing, whereas he wrote effusively when it came to drawing Christ's family tree. In doing so, he started each line with a small initial, in accordance with a graphic scheme that entailed placing three generations on each line, leaving the last part of the line blank. Finally, f. 136, which hosts very spaced out writing, is far from lacking in decorative elements.

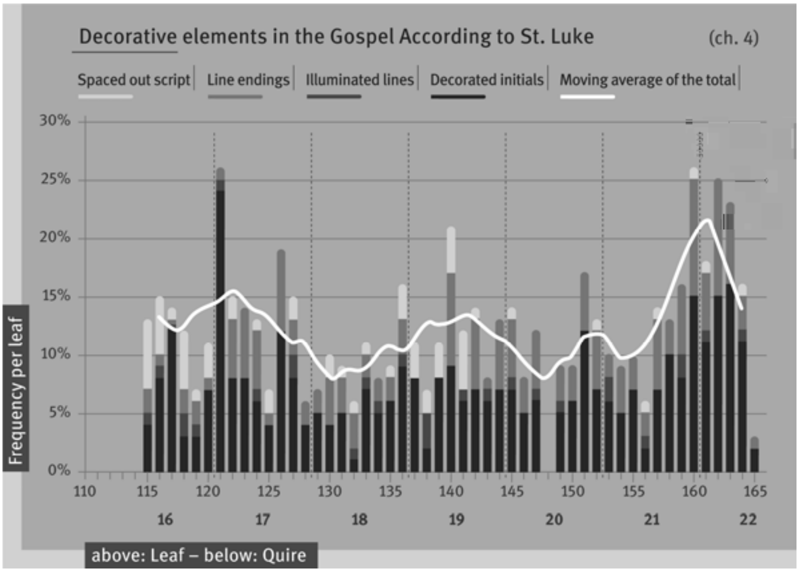

Chart 4: Decorative elements in the Gospel According to St. Luke

With respect to the insertion of decorative elements, Herimann did not have much choice in the matter. His scheme obliged him to terminate Eusebian sections at the end of a line and to start them with an ornamented letter, and to place a decorated line at the beginning of each *breve*. If Herimann checked the density of his writing less frequently in quire 18, this was perhaps because the number of Eusebian sections, the ornamentation linked to them and their insertion into arcades—the cause of continual interruptions in the text—was very low and did not demand his close attention. Quire 18 therefore represents a portion of text that Herimann was able to transcribe quite quickly.

4 Cyclical components

The theory behind time series analysis presupposes that the series from which one has extracted a trend contains only random fluctuations and potential cyclical components. To confirm the presence of the latter, a simple method consisting in autocorrelation can be employed: each *y* value is placed in correlation with the previous values (i.e. time lag 1, time lag 2, etc.), up to the beginning of the series. The coefficients of correlation obtained in this way can reveal, if need be, any manifestations of a cyclical kind.

In the case which concerns us here, autocorrelation did not furnish very high values, but it did make it possible to outline a sufficiently unequivocal model. Herimann's writing rhythm is marked by a 'five phase' cycle: the coefficients decrease to time lag 4, rise again to time lag 5, descend once again to time lag 9, then rise to time lag 10, and so on (Chart 5 shows the entire correlogram, both for the raw data and those reduced by the trend). Since each page was divided exactly into five sections, this model revealed a cycle within the written page (an 'intra-page' cycle): at the beginning of the page the writing density is relatively high; towards its end, it tends to decrease. In comparison to the average width (3.70 mm), the fluctuation is only ±2.5% (ranging from -0.09 to +0.09 mm). This is a seemingly small amount, but it is quite large if one compares the fluctuation with the extremes in the script variation observed in the overall volume (±15%). Expressed as a quantity of letters, these percentages signify that the first four lines of the page each contain an extra letter, and the last four lines one letter less.

Could it be that at the beginning of each page Herimann sought to strike a balance with the excessive width of the script at the end of the previous page, as he did at the beginning of quire 19? This may be so, but the cycle brought to light could equally be the product of the scribe's concern to gain a head start at the beginning of the page so as to be able to cope with the limitations imposed by the prior planning of the text.[32]

32 The 'intra-page' cycle identified in Herimann's work is far from what one might expect. Normally, the presence of large and empty pages instead encourages the creation of wider interline spaces and wider spaces between words, whereas in smaller pages or very full ones the writing density tends to increase. Concerning the correlation between the size of writing and the dimensions of the page, see Wiegand 1953/54, 230–266, and 601–606.

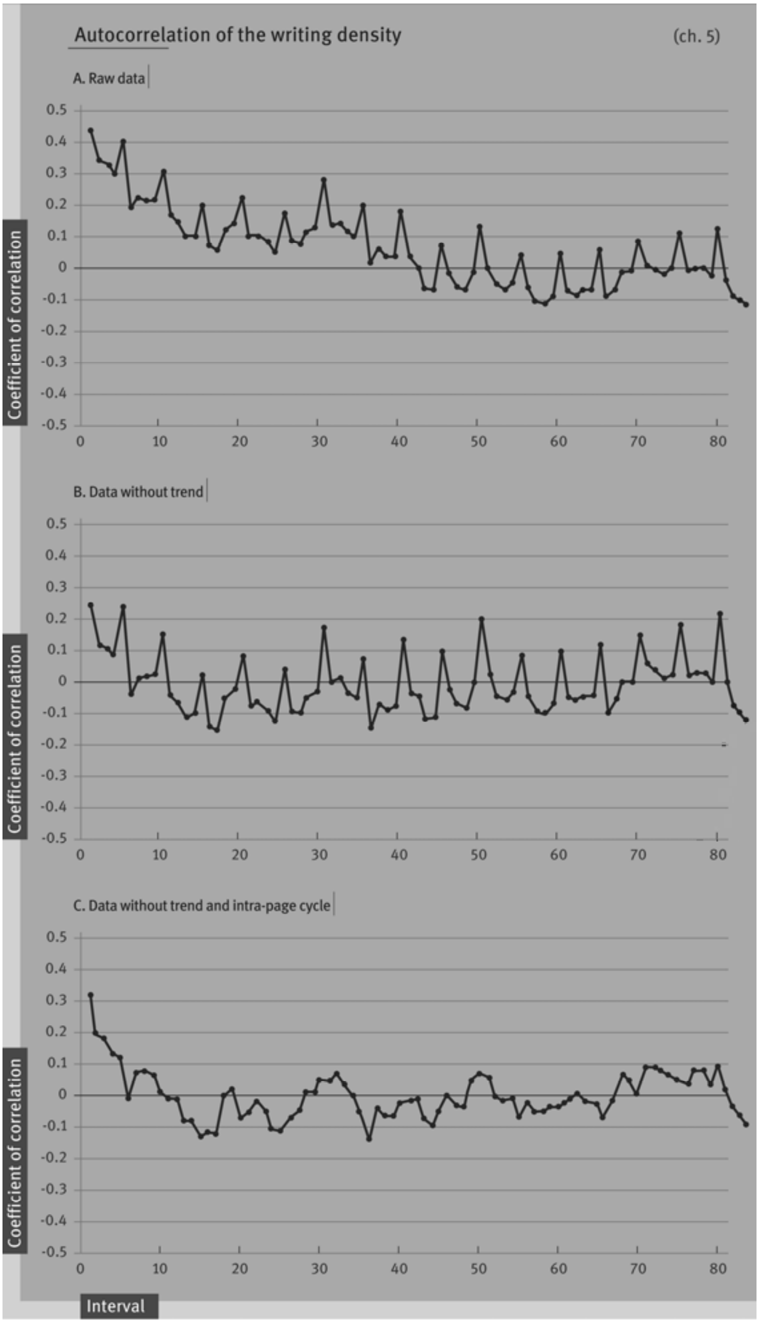

Chart 5: Autocorrelation of the writing density

Up to this point, we have only considered the regular cycles that consistently appear throughout the Gospel according to St. Luke. We shall continue to do likewise, since we must forswear a minute subdivision of the analysed material so as to avoid allocating an excessive weight to the extreme random values. In any case, one should not forget that Herimann's writing rhythm underwent some variations during the transcription of the Gospel according to St. Luke; hence, the 'intra-page' cycle is always present in all the quires[33], but it is a lot more pronounced in the last four (see Tab. 3). As for the variations that characterise the passage located between quires 18 and 19, they were addressed when we discussed the trend.

The correlograms provide some further clues, albeit less distinct, on the existence of some other rhythms. An examination of the positive correlations (see Chart 5b) reveals some additional important values for time lags 20, 30, and 50. Beyond time lag 50 the correlations become weaker, but they increase without discontinuity (in increments of 5) up to time lag 80. However, the positive correlations disappear if one eliminates the 'intra-page' cycle.

Extent of the intra-page cycle within quires 16–18 and 19–22 (tab. 3)

Lines	Quires 16–18	Quires 19–22
1–4	-0.073 mm	-0.102 mm
5–9	-0.020 mm	-0.028 mm
10–14	0.002 mm	0.005 mm
15–18	0.030 mm	0.016 mm
19–22	0.060 mm	0.110 mm

Tab. 3: Extent of the intra-page cycle within quires 16–18 and 19–22

Some more or less regular intervals also appear in accordance with the strongest negative correlations (time lags 6, 15, 25, 36, 44, 55 and 66). Given that this interval between ten measurements coincides with the sweep of two pages, one can reasonably suppose that there is a negative correlation between *recto* and *verso* pages (an 'inter-page' cycle). Even so, the correlogram shows that this is a weak

33 The weakest cycle is found in quire 17, with extremes ranging from -0.041 to 0.058.

relationship and is not statistically significant:[34] the average difference between the *rectos* where the writing is most dense and the *versos* where it is most spaced out is only ±0.014 mm, that is to say ±0.4%. In addition, one notices that the 'intra-page' and 'inter-page' cycles overlap, so the writing density is clearly greater in the first section of the *rectos*, and a lot less so in the last section of the *versos*.

None of the methods employed made it possible to identify any other writing rhythms with certainty, a state of affairs which is not unrelated to the deficiency of the cycles that we shall now discuss. In the case of another cycle, which corresponds to the hair and flesh sides of the skin ('hair/flesh' cycle), this failure could be due to irregularities in the assemblage of the bifolia. In fact, in the Gospel according to St. Luke, Herimann twice breaks Gregory's Rule (in quires 19 and 21), so much so that the cycle of four pages that characterises the 'hair/flesh' alternation is interrupted.[35] In any case, the data analysis revealed that Herimann's script is slightly more dense on the flesh side than on the hair side. The average width differs by ±0.027 mm, that is to say by about ±0.7%. In this situation, too, superimposition with the 'intra-page' cycle results in a relatively denser script in the first section of a flesh side page, and a relatively more spaced out one in the final section of hair side page. Given that we noticed the same type of emphasis in the 'inter-page' cycle, the three cycles can be superimposed upon each other.[36] This phenomenon is illustrated in Chart 6: the difference between the two extremes ranges from -0.13 mm to +0.11 mm.

The 'hair/flesh' cycle in the volume transcribed by Herimann is indistinct and does not allow us to draw any sweeping conclusions. The differences in density

34 Once the trend and the 'intra-page' cycle had been eliminated, a separate test carried out on quires 19–22 produced some slightly clearer results. The gaps are located at time lag 15 (r = 0.19), time lag 25 (r = 0.10) and time lag 36 (r = 0.18), as well as at time lags 30–32 (r = 0.11–0.12), time lags 50-51 (r = -0.04–0.07) and time lags 79-80 (r = 0.11–0.12). In comparison to quires 16–18, here the autocorrelation model is easier to interpret, despite the values being lower.

35 Gregory's so-called 'rule', which holds that in manuscripts of Late Antiquity and the Early Middle Ages quires should commence with the hair side and that opposing pages should always present the same side of the skin, is twice broken in the Gospel according to St. Luke: the first time in the two inner bifolia of quire 19, the second in the two outer bifolia of quire 21. In quire 19, when the *rectos* of pages are considered, the hair (H) and flesh (F) sequence is as follows: HFFH/FHHF, and in quire 21: FHHF/HFFH.

36 The cycles were not analysed on a page-by-page basis, but rather section-by-section, whilst the averages cited for the 'inter-page' and 'hair/flesh' cycles always relate to the entire page.

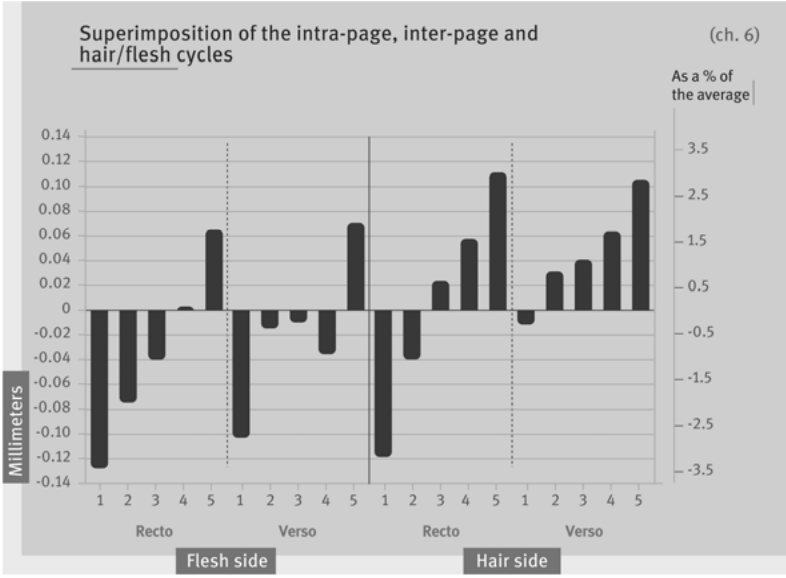

Chart 6: Superimposition of the intra-page, inter-page and hair/flesh cycles

between the two sides of the skin could be due to technical considerations. Having examined twenty Greek manuscripts, Stig Y. Rudberg[37] had already remarked in 1958 that the writing on the flesh side is denser than that on the hair side. According to the said author, the difference between the two sides is far more conspicuous in volumes where the hair side has a particularly rough surface, and is therefore not very well finished. The manuscripts examined by Rudberg were without doubt written on parchment made from goat or sheepskin. Such skins exhibit plain-to-see traces of the hair follicles typical of the animals concerned. Manuscripts whose parchment is smooth, and therefore better finished on the hair side than on the flesh side, only exhibit small differences in writing density. Now, in the Gospels of Henry the Lion, one only finds parchment sourced from calves, where both sides show scarcely any difference in surface quality. Because the hair side of sheets was very well finished, the difference in writing density is minimal.

In examining the raw data, a glimpse of the existence of yet another cycle was caught: if we exclude quire 17, one observes that the writing is denser in the first

37 Rudberg 1960, 528–539. J. P. Gumbert of the University of Leyden kindly provided me with this pointer.

leaves of a constituent quire than in the last. However, the cycle is not without interruption: on the first five leaves the writing density steadily decreases; the writing contracts again on the sixth leaf and then becomes even more spaced out on the last (quires 16, 18, 20, 21). The density changes from -0.025 mm on the first leaf to +0.027 mm on the fifth, then from -0.046 mm on the sixth to +0.052 mm at the end of the quire. It could be this rhythm that accounts for the fact that the autocorrelation measurements are higher at time lag 30 (cycle of three leaves), time lag 50 (cycle of five leaves), and time lag 80 (full quire cycle).

The differences are more significant if one excludes quire 17 (see Chart 7),[38] which differs from the norm in more ways than one[39]. In the second part of the Gospel according to St. Luke, in particular, the beginning of the quire represents a caesura, after which Herimann resumes his work using a more compressed script. A new correction of the writing density seems to coincide with the quire's central bifolia (see Chart 3). It is possible that this correction marks the transition to a new work phase. The end of the quire very likely coincided with an interruption in the copying process—as well as, perhaps, with the passage from the central bifolium to the sixth leaf. Nevertheless, this observation does not allow us to go any further; we can only say that Herimann often compressed his script at the beginning of a quire and did likewise once the halfway point had been passed.

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38 The averages for all the sections, after the elimination of the trend and the 'inter-page', 'intra-page' and 'hair/flesh' cycles, are shown in Chart 7. Quire 17 is excluded from the graphic representation (see the successive note). This is why the highest figures quoted differ from those shown in Chart 7. To boost the visual impact of the graph, we used the moving averages of period 10 (corresponding to the number of sections involved in an 'inter-page' cycle). Regarding the periodisation of the moving averages, see Thome 1992, 77ff.

39 Quire 17, which commences with the genealogical sequence, each line being embellished with an illuminated initial (see Chart 4), does not provide any unmistakable glimpses of the cycles that we have observed elsewhere. There is only one clearly discernible phenomenon: the writing is more compressed at the top of the page than at the bottom (see, however, note 33). Nevertheless, this result must not be overestimated, because the section in f. 125v, with an average density of 4.11 mm, clearly diverges from the norm (see Chart 3). This difference is not due to the fact that Herimann adopted in this instance a much more spaced out hand than that used in the neighbouring lines, but rather to the fact that the four lines concerned contain a considerable number of wide letters (including 15 *m*'s), and we know that the impact of this factor can be particularly sensitive in small samples. It should also be said that, in contrast to what happens elsewhere, quires 17 and 19 are characterised by the use of very thin parchment. The choice of such a writing support could have exerted an influence on the writing density, but this hypothesis would have to be confirmed across a much larger sample. Given that the behaviour observed in quire 17 is abnormal, its inclusion in the calculations tends to diminish the cycles observed in the other quires. These are above all the 'intra-page' and 'hair/flesh' cycles which, in the latter case, are more pronounced than they appear to be in Chart 6.

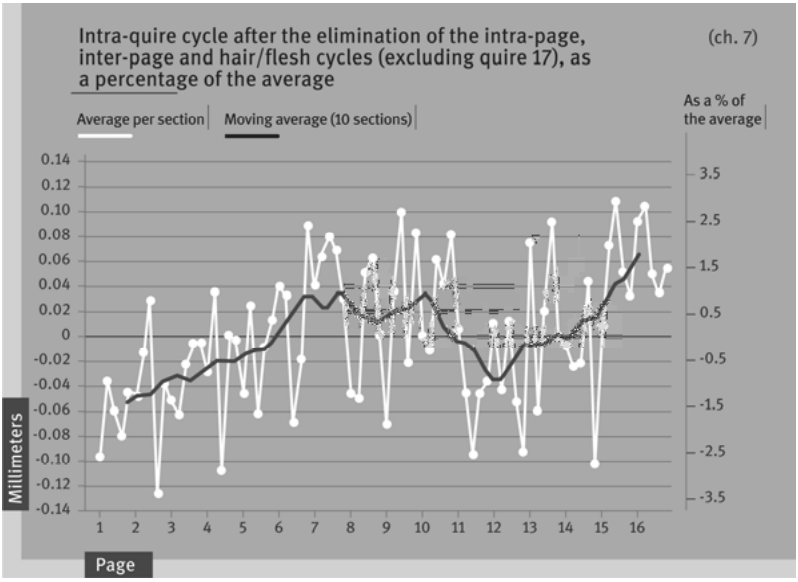

Chart 7: Intra-page cycle after the elimination of the intra-page, inter page and hair/flesh cycles (excluding quire 17), as a percentage of the average

The superimposition of all the cycles generates differences of ±0.16 mm. Close to 30% of the variations in writing density in Herimann's work should only be attributable to the trend and the cyclical components (inasmuch as one also interprets statistically insignificant recurrences as cycles). The 'intra-page' rhythm exerts an influence on all the other cycles. When one successively eliminates all the cycles, their respective weights in the standard deviation summary becomes clear (see Tab. 4).[40]

40 The elimination of each of the cycles is rather problematical, hence the procedure adopted in this study is not the one typically used in classical time series analyses. In fact, the benchmark procedure used for all operations was the moving averages method, which is often employed when making seasonal adjustments. This makes it possible to calculate averages free of cyclical influences for each juncture in a particular phase of a series (this process is described in all specialised manuals; see, in particular, Esenwein-Rothe 1976, Leiner 1982 or Thome 1992). However, in the present study, this method can only be partially applied. Accordingly, the 'hair/flesh' cycle, owing to the exceptions observed in quires 19 and 21, loses its regularity. Moreover, strict application of this method to the quire cycle for all the sections of each page would have resulted in the disappearance of unique values whose analysis was impossible: Chart 7 shows that, if the moving averages taken overall constitute a valid explanatory model, the values for the different sections undergo some strong fluctuations. Taking these problems into account, two methods for the elimination of the

Reduction of the standard deviation once the trend and cyclical components have been eliminated (tab. 4)

Eliminated component	Standard deviation	Raw data (%)
Raw data	0.179	100
Data without trend	0.153	85.5
After the elimination of the intra-page cycle	0.142	79.3
After the elimination of the inter-page cycle	0.140	77.9
After the elimination of the hair/flesh cycle	0.136	75.6
After the elimination of the intra-quire cycle	0.133	73.9

Tab.4: Reduction of the standard deviation once the trend and cyclical components have been eliminated

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cycles were tried out simultaneously, namely the 'deviation between the phase averages' method and the 'averages' method, the latter of which consists in simply subtracting from the value of each section the overall average of all the sections that have the same properties (position on the page, *recto*/*verso*, hair/flesh side). The test was carried out on the two most conspicuous and least disrupted cycles, namely the 'intra-page' and 'inter-page' cycles. As one might expect, the results obtained are largely speaking identical (the differences at the third decimal point could be attributable to rounding errors or to the loss of extreme data that affects the 'deviation between the phase averages' method). In accordance with the test protocol, we proceeded in the following way: for each of the sections represented in Chart 6, by applying the 'averages' method, the 'intra-page' and 'inter-page' cycles were successively subtracted from the data reduced by the trend. Next, the quire cycle was eliminated leaf-by-leaf according to the averages cited in the text, including, therefore, quire 17. This means that, contrary to what takes place when the 'deviations between the phase averages' method is applied, the same value was subtracted from the all of the ten sections on the same leaf. In addition, when it comes to dealing with data which have had the trend subtracted, they will be processed using the method described above. Furthermore, to measure the reduction in the standard deviation (Tab. 4), the data which have had the trend subtracted were reduced by the averages of the four cycles (i.e. 'intra-page', 'inter-page', 'hair/flesh', and 'inter-quire'). Finally, it should be pointed out that, according to the results of the Durbin-Watson tests, the data minus the trend and the cycles, that is to say the 'white noise', which in theory should be free from any form of regularity, in any event do not satisfy the autocorrelation criterion. In the test, a score of 0 indicates a positive autocorrelation, while a score of 4 indicates a negative autocorrelation, and a score of 2 a complete absence of any correlation. Now, the result is 1.48, which is below the threshold values (1.81-2.19), and therefore the null hypothesis (calculated according to the Theil-Nagar method with a probability threshold of 1%) is not acceptable. Concerning the test procedures, see Ostrom 1978.

4.1 Non-cyclical trends in the writing density

The cyclical nature of a series can be demonstrated through the application of various methods. One of these consists in fitting the evolution model underlying the data to a series of sine/cosine curves. If the weighting of a cycle is sufficiently strong, the corresponding sine/cosine curves exhibit a marked range. Given that all the ranges are not necessarily expressions of a cyclical phenomenon, various tests exist which are designed to determine whether any phenomenon whose appearance seems to be periodic can indeed be considered a cycle. As regards the writing density, the probability that the range of the 'intra-page' cycle might be attributable purely to chance is less than 0.1%.[41] At the 0.1 and 1.0 percent level, however, this cycle is also the only statistically significant period (see Chart 8a).[42]

In this situation, the weaker cycles only become interesting when they evolve in parallel with the cycles of other characteristics, in particular the number of decorated initials, line endings and Eusebian sections. In order to avoid bias which, on account of the method adopted for the survey, could have affected some of the units examined due to the presence of initials and Eusebian sections, in Charts 8b and 8c the frequencies corresponding to passages 2 and 3 have been systematically reduced to 4/5. This operation does not have any effect on the cycles that will be discussed hereinafter, but it does attenuate the effects of the 'intra-page' cycle that were accentuated by the presence of the aforementioned elements.[43]

41 We applied the Walker test. For information on the calculation of frequency and the test's methodology, see Billeter / Vlach 1981, 59 onwards. An analogous method is proposed by Schlittgen / Streitberg 1984, 42, whose results, despite being different, are in any event largely speaking similar.

42 With respect to the writing density, it should be borne in mind that, as we have already mentioned more than once, quires 19 and 21 do not respect Gregory's Rule, and that quire 17 does not exhibit any cycles. A periodogram, performed without taking into account these 'abnormal' quires, revealed that if one excludes the 'intra-page' cycle, the 25, 10, 36-41 and 20 cycles clearly distinguish themselves from the others (even if one eliminates the last).

43 Since sections 2 and 3 contain five lines as opposed to the four in sections 1, 4 and 5, the decorative elements and the chapter openings are more numerous. In certain cases, the 20% reduction in frequencies generates incongruous results (e.g. the presence of 0.8 Eusebian sections or ornamental initials), but this was necessary in order to prevent the appearance of visible cycles linked solely to the difference in length among the units examined.

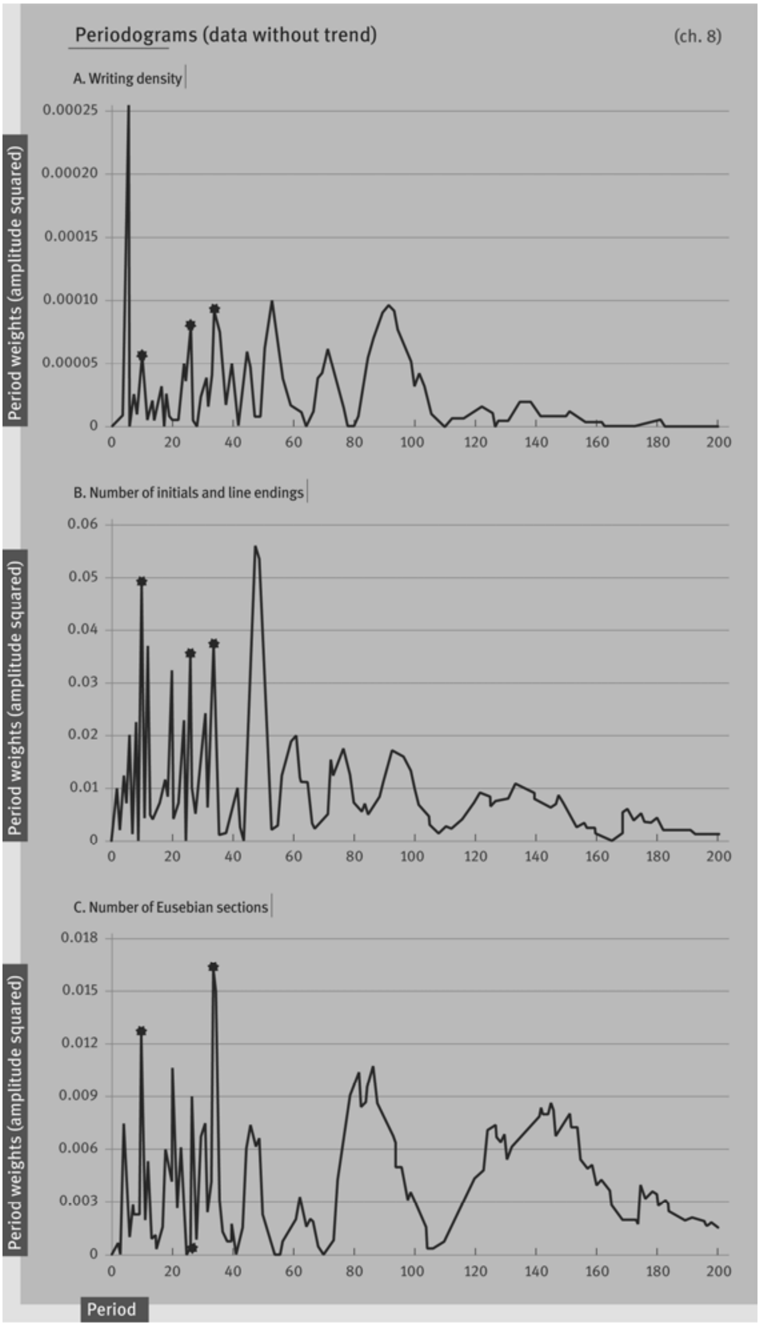

Chart 8: Periodograms (data without trend)

Leaving aside the differences in detail, it becomes clear that certain cycles have the same appearance in terms of writing density, ornamental elements and Eusebian sections. This is particularly true of cycles 10, 26[44] and 34, marked by an asterisk in Chart 8, but there is no point in analysing them here. We have already stated that these cycles are not statistically significant; on the other hand, all hypotheses on the cyclical nature of the Eusebian sections prove to be without basis if one considers the fact that they are textual elements whose frequency does not depend on the choices made by the scribe. Concerning the only element which might be open to interpretation—cycle 10 (the 'inter-pages' cycle)—this turns out to be a structural effect linked to the distribution of ornamental initials and Eusebian sections:[45] the frequency of these two characteristics is greater on the *rectos* than on the *versos* (among 556 ornamental initials, 314 are found on the *recto* and 158 on the *verso*). Therefore, one is not dealing with a true writing cycle, but rather the product of pure chance during the division of the text.

Nevertheless, the periodograms furnish information on the concordance of a certain number of characteristics that we have already discussed in relation to the trend. These concordances are rather difficult to pin down, because Herimann did not always modify his writing in the same way: thus, even if he often compressed his script immediately before or immediately after the ornamental band that preceded a *breve* (for example on ff. 127v, 132r, 143v), this did not always happen, so the average is scarcely 2% lower than the overall average.

A similar phenomenon shows up in the Eusebian sections: most of the time the passages that do not start with a Eusebian section tend to have writing which is more spaced out, whereas in those in which one finds several sections the writing is denser. Given that the tendency persists even after the elimination of the trend and the cyclical component (see Tab. 5), this phenomenon clearly does not depend on the distribution of the text between the *rectos* and *versos* of sheets.[46]

44 Conversely, in the Eusebian sections, cycle 27 is quite pronounced, with a root-mean-square amplitude of 0.009. However, it is cycle 26 which, in Chart 8c, is marked by an asterisk.

45 Section 1 of f. 118v and section 343 of f. 166v were not taken into consideration.

46 In theory, the correlation between the Eusebian sections and writing density could stem from the fact that, as already mentioned, the start of these sections is most often found on the *recto* rather than the *verso* of a sheet. In this case, the decisive factor in the correlation can only be the scribe's habit of employing a denser script on the upper side of a sheet. Since the data presented in Table 5 have already been reduced by the trend and the cycle components have been subtracted, the 'intra-page' cycle has already been eliminated. Given that 30% of the passages that start with one or more Eusebian section are executed in a very dense script, one can only conclude that there is a correlation between dense writing and Eusebian sections, which, in our opinion, is equally likely at a concrete level.

Writing density in relation to the frequency of Eusebian sections (trend and cycles-adjusted data for writing density: percentage deviation of the mean) (tab. 5)

Frequency of Eusebian sections per page section	Denser	<- Writing density ->			Wider	
	<-3%	- 1 to - 3%	- 1 to 1%	1 to 3%	> 3%	Total
Without Eusebian section	43 (16.5)	47 (18.0)	56 (21.5)	51 (19.5)	64 (24.5)	261
One Eusebian section	40 (21.5)	35 (18.8)	45 (24.2)	33 (17.7)	33 (17.7)	186
Two to four Eusebian section	22 (30.1)	14 (19.2)	14 (19.2)	13 (17.8)	10 (13.7)	73
Total	105	96	115	97	107	520

Frequency with percentage of lines in brackets

Tab. 5: Writing density in relation to the frequency of Eusebian sections (trend and cycle-adjusted data for writing density: percentage deviation of the mean)

One should interpret this behaviour in relation to the way in which Herimann conceived the presentation of the page. In most cases, he endeavoured to start a Eusebian section on a new line. In addition, since the design of the *mise en page* constitutes a kind of block, he tried equally hard to avoid leaving a blank space on the preceding line or, failing that, to reduce the space to a minimum by filling it with a line ending in the form of a decorated bar. Such line endings are not very long, and without doubt they follow a plan; in fact, in the Gospel according to St. Luke, the endings only rarely attain the length of half a line, and one no longer encounters the complicated filling elements which, by contrast, characterise the Gospel according to St. Matthew. For this reason, Herimann worked using the available space and regulated the density of his writing so as to ensure its justification on the right. Now, he often succeeded in accomplishing this feat, but not always: a series of Eusebian sections concludes, indeed, before the middle of the line is reached. In this situation, in order to completely avoid committing an aesthetic blunder, Herimann evidently relinquished his conceptualisation of the page, because he avoided spacing out his text or inserting line endings, and instead preferred to start the following section with its initial on the same line.

In light of these considerations, a certain number of incongruities can be explained. Herimann used writing density to orchestrate the linkage between the text and the page, hence his writing strategy depended on the accuracy of his projections. Indeed, in certain cases, in proximity to some Eusebian sections we can observe a compression of the writing; in other instances, no modification can be observed; in still others, one observes a tendency to enlarge the width of the writing.

Table 5 has been constructed on the basis of Eusebian sections, since the concordance between writing density and the presence of ornamental initials is a lot less clear. The weakness of the relationship may be linked to the fact that the initials, which occur particularly often at the beginning of the Gospel according to St. Luke, appear equally often in places that do not involve a change of line or which, as in the genealogical tree of Christ, are not linked to a particular distribution of the surrounding script.

The fluctuations in the writing density that remain following the elimination of the trend and the cyclical component are certainly greatly diminished, but they are far from being negligible because, in the most extreme cases, they can attain a value of ± 0.5 mm. Some of them, as we have already seen, are closely linked to the Eusebian sections and the beginning of the *breves*. In fact, if one only considers the most compressed passages, where the width of the writing is more than 0.2 mm below the average, still 14 out of a total of 35 contain the beginning of a *breve* or several Eusebian sections. As for the 28 sections in which the mean width is exceeded by more than 0.2 mm, there is only one text passage with the beginning of a *breve* and another one with two Eusebian sections. Therefore, one must conclude that the organisation of the ornamental programme around the beginning of a *breve* or a Eusebian section would have led the scribe to pause for a moment in order to calculate how much space would be necessary to accommodate the decorative elements, and to compress his writing accordingly.

By applying further methods and by working on a larger volume of material, one could doubtless discover some other factors that exerted a direct influence on the scribe's writing rhythm. But there will always be text passages in which the writer has adapted his writing density to needs that can be traced in detail but not summarized in a system. Seen from this standpoint, we can safely say that Herimann also worked on a line-by-line basis.

Furthermore, the analysis of residual fluctuations would not filter out the measurement errors that are inherent to the way in which the data are collected. We have already pointed out the drawbacks which result from the choice of the average width of letters as an indicator of writing density, given that this parameter does not take into account the effective width of each letter of the alphabet, nor the variations in its frequency in the text. The comparison with what we have termed the 'standardised width' of letters revealed that, even if one divides the text into groups of four or five lines, the error rate is not reduced to nil. Should one wish to be convinced, it would suffice to examine the extreme values: among the passages where the width (once the trend and the cyclical component have been eliminated) is below -0.2 mm in relation to the average, one finds 31 where the frequency of *m* is weak (2-6 in groups composed of four lines, 2-7 in those composed of five lines). Only four sections contain more than 6 or 7 *m*'s. In contrast, in the 28 passages located symmetrically above +0.2 mm, the frequency of this letter is manifestly greater, since one observes 24 cases where it appears 7-15 times (in groups composed of 4 lines), or 8-15 times (in passages composed of 5 lines). The number of *m*'s is lower than these values in only four sections.

Clearly, this bias raises some doubts about the output of our research: can the impact of errors have a noticeable effect on the results obtained? The answer to this question would be affirmative only if it turned out that the frequency of wide or compressed letters also varies in relation to the cycles identified in the writing—for example, when wide letters are less common at the beginning than at the end of a page, or rarer on the *recto* than on the *verso* of a leaf, or less common in proximity to the *breves* or at the beginning of Eusebian sections than in the main body of the text. We can see that the danger is not great, because the errors in measurements, even if they can explain certain deviations with respect to the data series, exert no influence on the rules that govern Herimann's writing density. In fact, the scribe's writing develops in a far less capricious way than a superficial inspection might lead one to believe, instead following rhythms which repeat themselves page after page. Further research would certainly be necessary in order to be able to establish whether or not the rhythms we have identified are indeed a unique feature of this scribe, or instead reflect a *modus operandi* shared by copyists working in other scriptoria.

Annex

Number of letters per seftion and length of section (H = Hair, F = Flesh) 1 of 7

Quire	Leaf	H/F	Section	Letters	Length (mm)
16	114 v	h	1	150	504
			2	128	475
			3	225	751
			4	172	593
			5	159	589
	115 r	h	1	170	600
			2	206	750
			3	186	660
			4	171	600
			5	167	600
	115 v	f	1	88	314
			2	195	694
			3	197	718
			4	153	568
			5	168	600
	116 r	f	1	157	569
			2	202	726
			3	180	698
			4	153	578
			5	161	582
	116 v	h		158	574
			2	115	420
			3	200	744
			4	1 59	586
			5	1 52	584
	117 r	h	1	167	576
			2	195	718
			3	195	719
			4	162	564
			5	157	581
	117 v	f	1	124	410
			2	205	707
			3	214	732
			4	169	595
			5	167	600
	118 r	f	1	175	578
			2	210	732
			3	206	708
			4	92	331
			5	162	578
	118 v	h	1	108	373
			2	207	738
			3	197	738
			4	164	574
			5	176	602
	119 r	h	1	162	584
			2	210	750
			3	210	750
			4	165	594
			5	126	468
	119 v	f	1	168	582
			2	192	700
			3	166	550
			4	159	571
			5	164	594
	120 r	f	1	167	584
			2	209	750
			3	202	739
			4	160	594
			5	154	557
	120 v	h	1	143	548
			2	188	707
			3	187	694
			4	134	504
			5	134	522
17	121 r	h	1	146	522
			2	176	649
			3	170	648
			4	133	510
			5	102	390
	121 v	f	1	117	418
			2	215	768
			3	209	768
			4	170	619
			5	154	581
	122 r	f	1	164	592

(H = Hair, F = Flesh)

Quire	Leaf	H/F	Section	Letters	Length (mm)
			2	207	757
			3	212	756
			4	106	389
			5	141	524
	122 v	h	1	166	577
			2	213	755
			3	196	692
			4	161	575
			5	172	614
	123r	h	1	149	541
			2	218	750
			3	190	630
			4	160	594
			5	136	478
	123 v	f	1	167	590
			2	209	758
			3	190	715
			4	159	588
			5	157	568
	124 r	f	1	164	592
			2	162	570
			3	155	538
			4	160	586
			5	167	611
	124 v	h	1	181	600
			2	221	751
			3	192	696
			4	158	584
			5	157	575
	125 r	h	1	172	593
			2	214	757
			3	205	769
			4	167	576
			5	163	593
	125 v	f	1	151	528
			2	205	757
			3	203	751
			4	163	577
			5	139	571
	126 r	f	1	159	558
			2	203	740
			3	178	617
			4	162	590
			5	146	515
	126 v	h	1	160	568
			2	180	664
			3	206	731
			4	166	606
			5	165	587
	127 r	h	1	155	572
			2	207	712
			3	205	721
			4	111	391
			5	129	490
	127 v	f	1	126	470
			2	203	751
			3	149	568
			4	159	583
			5	163	600
	128 r	f	1	158	593
			2	206	744
			3	188	702
			4	167	600
			5	164	607
	128 v	h	1	145	572
			2	195	742
			3	209	767
			4	160	610
			5	150	574
18	129 r	h	1	141	541
			2	184	710
			3	184	671
			4	154	593
			5	146	571
	129 v	f	1	164	602
			2	206	751

(H = Hair, F = Flesh)

Quire	Leaf	H/F	Section	Letters	Length (mm)
			3	194	743
			4	156	600
			5	151	598
	130 r	f	1	163	592
			2	179	668
			3	201	720
			4	132	503
			5	154	595
	130 v	h	1	165	613
			2	190	719
			3	173	677
			4	147	600
			5	152	608
	131 r	h	1	136	482
			2	170	650
			3	189	731
			4	143	574
			5	151	594
	131 v	f	1	166	613
			2	195	762
			3	190	748
			4	151	600
			5	150	604
	132 r	f	1	154	598
			2	190	760
			3	187	716
			4	116	464
			5	111	433
	132 v	h	1	149	593
			2	189	744
			3	183	770
			4	148	608
			5	150	606
	133 r	h	1	150	602
			2	196	746
			3	141	546
			4	146	584
			5	148	593
	133 v	f	1	121	432
			2	193	750
			3	192	730
			4	154	586
			5	147	613
	134 r	f	1	164	600
			2	206	748
			3	207	766
			4	145	539
			5	147	563
	134 v	h	1	145	589
			2	184	720
			3	148	582
			4	151	592
			5	164	614
	135 r	h	1	167	611
			2	198	719
			3	189	745
			4	147	607
			5	146	577
	135 v	f	1	162	606
			2	196	739
			3	172	683
			4	139	524
			5	169	613
	136 r	f	1	165	607
			2	192	731
			3	153	618
			4	119	462
			5	107	426
	136 v	h	1	147	553
			2	181	725
			3	176	701
			4	139	533
			5	145	553
19	137 r	h	1	177	568
			2	201	712
			3	214	728

(H = Hair, F = Flesh) 4 of 7

Quire	Leaf	H/F	Section	Letters	Length (mm)
			4	163	554
			5	137	473
	137 v	f	1	165	554
			2	210	730
			3	206	728
			4	176	599
			5	166	606
	138 r	f	1	166	586
			2	125	438
			3	202	743
			4	159	564
			5	123	431
	138 v	h	1	158	593
			2	193	730
			3	212	738
			4	157	565
			5	158	586
	139 r	f	1	141	491
			2	191	692
			3	208	745
			4	160	601
			5	145	577
	139 v	h	1	163	605
			2	176	652
			3	203	732
			4	164	596
			5	138	546
	140r	h	1	141	463
			2	188	727
			3	203	757
			4	139	547
			5	110	427
	140 v	f	1	146	494
			2	200	677
			3	169	610
			4	158	575
			5	126	451
	141 r	f	1	138	426
			2	209	707
			3	212	749
			4	162	598
			5	166	599
	141 v	h	1	120	454
			2	181	650
			3	191	730
			4	161	594
			5	151	596
	142 r	h	1	154	598
			2	199	734
			3	203	743
			4	158	604
			5	156	589
	142 v	f	1	132	482
			2	167	620
			3	181	677
			4	166	583
			5	147	552
	143 r	h	1	154	577
			2	195	716
			3	196	734
			4	149	592
			5	156	600
	143 v	f	1	161	598
			2	200	736
			3	194	718
			4	113	416
			5	172	601
	144r	f	1	169	588
			2	193	732
			3	201	750
			4	159	598
			5	134	508
	144 v	h	1	164	598
			2	186	671
			3	164	610
			4	142	509

(H = Hair, F = Flesh)

Quire	Leaf	H/F	Section	Letters	Length (mm)	Quire	Leaf	H/F	Section	Letters	Length (mm)
			5	155	560				3	207	760
20	145 r	h	1	167	558				4	162	594
			2	207	725				5	169	600
			3	150	571		149 r	h	1	181	598
			4	162	580				2	205	739
			5	135	514				3	172	670
	145 v	f	1	174	600				4	149	565
			2	157	563				5	127	508
			3	208	732		149 v	f	1	107	410
			4	63	203				2	203	755
			5	168	602				3	194	755
	146 r	f	1	155	515				4	152	593
			2	215	725				5	159	614
			3	188	682		150 r	f	1	162	602
			4	163	593				2	190	682
			5	156	600				3	185	670
	146 v	h	1	166	602				4	156	556
			2	187	740				5	152	583
			3	191	725		150 v	h	1	157	596
			4	162	595				2	204	752
			5	160	600				3	206	756
	147 r	h	1	139	467				4	158	605
			2	150	535				5	151	580
			3	196	727		151 r	h	1	148	545
			4	155	595				2	203	701
			5	152	594				3	181	677
	147 v	f	1	145	575				4	153	583
			2	168	656				5	158	560
			3	220	774		151 v	f	1	156	558
			4	169	617				2	202	720
			5	157	601				3	201	750
	148 r	f	1	160	589				4	161	599
			2	214	743				5	164	595
			3	201	744		152 r	f	1	159	600
			4	160	602				2	201	756
			5	163	602				3	176	637
	148 v	h	1	168	599				4	166	592
			2	206	755				5	144	546

(H = Hair, F = Flesh)

Quire	Leaf	H/F	Section	Letters	Length (mm)
	152 v	h	1	153	600
			2	169	654
			3	205	762
			4	129	510
			5	121	482
21	153 r	f	1	120	421
			2	213	733
			3	205	751
			4	159	595
			5	103	386
	153 v	h	1	166	595
			2	207	762
			3	191	762
			4	153	552
			5	154	580
	154 r	h	1	164	598
			2	212	752
			3	202	750
			4	156	602
			5	130	506
	154 v	f	1	167	580
			2	211	739
			3	210	720
			4	152	568
			5	163	599
	155 r	h	1	155	558
			2	194	724
			3	194	691
			4	177	599
			5	158	582
	155 v	f	1	168	593
			2	209	750
			3	205	744
			4	168	617
			5	155	605
	156r	f	1	169	592
			2	205	757
			3	139	542
			4	117	431
			5	155	611
	156 v	h	1	161	592
			2	195	718
			3	196	752
			4	153	607
			5	148	607
	157 r	h	1	164	602
			2	171	714
			3	176	728
			4	131	514
			5	120	486
	157 v	f	1	160	602
			2	184	731
			3	186	734
			4	162	613
			5	123	482
	158 r	f	1	152	540
			2	200	730
			3	208	722
			4	141	530
			5	149	565
	158 v	h	1	161	575
			2	177	644
			3	204	766
			4	154	590
			5	158	614
	159 r	f	1	156	578
			2	99	372
			3	180	678
			4	159	601
			5	148	599
	159 v	h	1	167	608
			2	178	673
			3	185	697
			4	145	574
			5	131	533
	160 r	h	1	118	419

(H = Hair, F = Flesh)

Quire	Leaf	H/F	Section	Letters	Length (mm)
			2	178	644
			3	185	721
			4	128	505
			5	121	470
	160 v	f	1	132	485
			2	176	689
			3	161	608
			4	131	492
			5	132	520
22	161 r	h	1	178	580
			2	119	418
			3	202	709
			4	149	530
			5	155	572
	161 v	f	1	153	552
			2	168	652
			3	202	736
			4	164	590
			5	164	599
	162 r	f	1	165	564
			2	157	569
			3	199	716
			4	140	511
			5	165	612
	162 v	h	1	162	610
			2	162	592
			3	193	703
			4	149	570
			5	135	518
	163 r	h	1	150	541
			2	162	584
			3	197	703
			4	133	517
			5	156	587
	163 v	f	1	172	590
			2	177	653
			3	206	710
			4	176	593
			5	145	571
	164 r	f	1	158	594
			2	197	708
			3	198	698
			4	164	592
			5	139	539
	164 v	h	1	136	497
			2	188	724
			3	191	722
			4	154	606
			5	86	330
	165 r	h	1	154	569
			2	178	652
			3	187	737
			4	161	592
			5	141	588
	165 v	f	1	166	605
			2	206	763
			3	192	752
			4	157	608
			5	156	608
	166 r	f	1	163	592
			2	167	626
			3	194	748
			4	125	481
			5	137	538

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