

A MORPHOLOGY OF MEDIEVAL NOTATIONS IN THE OPTICAL NEUME RECOGNITION PROJECT

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Abstract

The study of medieval notations depends on effective categorization of individual signs in order to facilitate a comprehensive understanding of their musical meaning. Over the past century, chant scholars have developed several kinds of neume tables which arrange and contextualize neumes either according to graphical type, chronology, or scribal tradition. Some neume tables contain longer strings of neumes that link certain notation conventions with performance traditions. The course of neume table development reads like a history of the study of early notations, itself, and reveals the evolving interests and pursuits of the scholars who created them. It also sets the stage for the latest use of the neume table as a reference for document analysis software applied to digital images of medieval manuscripts. Now, instead of presenting a static list of discrete signs, the neume table can be understood as a reflection of the notational variety and nuance of the hundreds of thousands of neumes contained in every book of liturgical chant. On this scale, ne-

ume tables help scholars to understand the use of medieval neumes in the same way a linguist understands the morphology of words. This article presents the principles on which this new kind of neume table has been developed and suggests the ways in which this new way of thinking might inform the discipline in the future.

Keywords: neume table, morphology of medieval notation, adialematic notation, medieval manuscripts, music encoding initiative - MEI, optical music recognition - OMR, Antiphonar Hartker from St. Gall Sang. Cod. 390 / 391, liturgical books in Latin

Ključne riječi: tabele neuma, morfologija srednjovjekovne notacije, adijastematska notacija, srednjovjekovni rukopisi, Inicijativa za kodiranje glazbe (*Music Encoding Initiative* – MEI), optičko prepoznavanje glazbe (*Optical Music Recognition* - OMR), Antiphonar Hartker iz St. Gallena Sang. Cod. 390 / 391, liturzijske knjige na latinskom jeziku

To characterise the Middle Ages as a time of ‘interdisciplinary’ thinking is to flirt with anachronism. Yet, as modern scholars who strive to see beyond the traditional boundaries of separate academic disciplines, the medieval conception of the universe as thoroughly and intimately connected seems compellingly new again. Bestiaries were reflected in psalters, philosophy and poetry intertwined, and music, mathematics, and astronomy were interchangeable expressions of the measurement of perfection. To be educated, in the Middle Ages, meant to be familiar with the *Septem Artes Liberales*, all in equal measure. Modern medieval specialists in one area inevitably find themselves venturing into far-reaching, ‘dragon’ territory, in pursuit of the medieval minds they study. Despite this, medieval musicological research might seem to the outside observer as a niche interest, bound up in dusty texts and forgotten rituals. Yet, as Jacques of Liège observed in the 14th century, »Music objectively extends to almost everything, God and created beings, corporeal and incorporeal, heavenly and human, theoretical and practical science.«¹ It is this same instinct for connection within and across the medieval world that leads scholars of the medieval world to reach outside their own disci-

¹ »Musica enim, generaliter sumpta, obiective quasi ad omnia se extendit, ad Deum et ad creaturas, incorporeas et corporeas, coelestes et humanas, ad scientias theoreticas et practicas«, Roger Bragard (ed.): *Jacobi Leodiensis Speculum musicae*, Corpus scriptorum de musica, vol. 3/1 [Rome]: American Institute of Musicology, 1955, 11.

pline to the cutting edge of technological development to provide newer and better tools for their research. The past several decades have seen the rise of groups such as the Digital Medievalist, the online journal² of which publicizes the results of many compelling projects such as Electronic Beowulf,³ Mapping Gothic France,⁴ and the Digital Image Archive of Medieval Music (DIAMM).⁵ Chant scholars have long benefitted from the use of computer databases to store and analyse the vast repertoire of centuries of monastic traditions, beginning with Andrew Hughes' electronic databases and transcriptions published as part of his *Late Medieval Liturgical Offices*,⁶ to the Cantus Database,⁷ an online resource containing indices for over 140 liturgical manuscripts, compiled by scholars all over the world.

More recently, digital tools are being developed to help not only with the storage and retrieval of information about chant, but in the study of chant itself. The Optical Neume Recognition⁸ project, part of a larger undertaking called SIMSSA⁹ (Single Interface for Music Score Searching and Analysis) to create an interface for all digitized music manuscripts, focuses on one of the earliest medieval notations, associated with the monastery of Saint Gall in Switzerland. Images of one fully notated and particularly well-known antiphoner with the shelf-mark Cod. Sang. 390 / 391, which represents this notation tradition are freely available online¹⁰ and form the backbone of the project. These images are scanned and individual neumes are identified, classified, and matched to a neume table that links each sign to its musical significance. This musical information is then expressed in a kind of XML specifically designed for music notation called the Music Encoding Initiative¹¹ (MEI), although the peculiarities of the notation system has required the creation of a new MEI schema.

In the case of the Optical Neume Recognition project, it is possible to pinpoint the nexus between medieval musical notation and cutting-edge computer technology: the neume table. Based on tradition of examining musical manuscripts that extends back at least a century, the existence of neume tables is a central component of Gregorian Semiology. Looking ahead to future collaboration with technology, however, the kind of information contained in these tables, and the way that

² <http://www.digitalmedievalist.org/journal/>

³ <http://ebeowulf.uky.edu/>

⁴ <http://mappinggothic.org/>

⁵ <https://www.diamm.ac.uk/>

⁶ Andrew HUGHES: *Late Medieval Liturgical Offices* vols. 1 and 2, Toronto: Pontifical Institute of Medieval Studies, 1994, 1996.

⁷ <http://cantus.uwaterloo.ca/>

⁸ <https://opticalneumerecognition.wordpress.com/about/>

⁹ <https://simssa.ca/>

¹⁰ <http://www.e-codices.unifr.ch/en/searchresult/list/one/csg/0390> and <http://www.e-codices.unifr.ch/en/searchresult/list/one/csg/0391>

¹¹ <http://music-encoding.org/>

information is expressed, must be comprehensible not only to a fellow chant scholar, but also a software program. Between scholars, differences of definition, description, and categorization are often ignored in order to gain research ground or come to new and interesting conclusions, but when working with computers, clarity, precision, completeness, and consistency carry the day. The Optical Neume Recognition project's neume table represents a step into this new world, in which each neume is described in a way that a computer program will not confuse it for another neume, including only reliable musical information and not speculation about the meanings of more complicated signs. This table can also be expanded to include other types of notation, thereby broadening its reach exponentially and increasing the power of digital technology in the realm of the medieval scribe. The application of the latest technology to the study of chant notation will accelerate our understanding of it and reveal deep graphic and musical connections that are impossible to find using traditional methods.

Neume Tables, a brief history

The study of medieval notations often begins with a neume table, a chart in which the Latin names of neumes forms one column and then representations of each shape are given in corresponding rows, just as medieval neume tables were usually laid out. There are at least 20 basic neumes to learn, and even more when compound neumes are added to this list, not to mention graphic modifications, alternative renderings, etc. For this reason, the clarity and precision of neume tables have long attracted chant scholars as the appropriate way to display their research.¹² Dom E. Cardine, a student of Dom A. Mocquereau at Solesmes, established the construction of neume tables as a reliable way of tracing a scribal tradition to its earlier sources and comparing these traditions to each other, laying the groundwork for the discipline of Gregorian Semiology itself, and focusing attention, in Cardine's generation and later, on adiaستمatic neumes.¹³ Most students of music history will have encountered one in their general textbooks somewhere near the beginning of the 'Medieval' chapter; those looking for a somewhat more expansive description will turn to the tables in musical encyclopaedia.¹⁴ More ad-

¹² Early examples include the research of Hugo RIEMANN: *Studien zur Geschichte der Notenschrift*, Leipzig: 1878– Tables III and IV and the earliest publications of the Solesmes monastery in the *Paléographie musicale* and *Études grégoriennes* series, among them the works of Dom. A. Mocquereau and Dom. Eugène Cardine.

¹³ Franz Karl PRASSL: Cardine, Eugène Alexandre OSB, in: *Die Musik in Geschichte und Gegenwart*, vol. Personenteil 4, Kassel: 1994, rows 184, 185. See also: Luigi AGUSTONI: *Die Gregorianische Semilogie und Eugène Cardine*, *Beiträge zur Gregorianik*, 1 (1985), 9-22, and Jacques VIRET: *Le Chant Grégorien et la Tradition Grégoriennes*, Lausanne: Editions l'Age d'Homme, 2001, 72-74.

¹⁴ The articles in both the Oxford Music Online (*New Grove*) encyclopaedia, found under »Neumes of the 11th and 12th centuries.« *Grove Music Online*. Oxford Music Online. Oxford University Press, ac-

vanced medieval scholars will sometimes find it necessary to construct their own neume tables while transcribing a particular source or comparing scribal traditions. Despite their ubiquity, however, a written history of neume tables – their construction, their evolution, their typologies – is nowhere to be found.¹⁵ Since the success of our current project relies on the accuracy, breadth, and robustness of the neume table we are currently finalizing for use in combination with document analysis software, it was important to understand the tradition that came before.

Conceptually, neume tables set out to do two things: describe the notation contained in one or several manuscripts; and define the musical meaning represented by the notation. The present study considered over 50 neume tables published in the past eighty years; while each table considered both the descriptive and definitional aspects of the neumes at hand, very rarely were any two tables alike in their construction. This is because the ends shape the means, and an author whose goal is to set out the general shapes of basic neumes with their Latin names will arrange things differently from an author who intends to situate a particular scribal tradition or manuscript source in a broader context for comparison, or even from an author whose aim is to identify scribal habits particular to a region by isolating certain graphic features in groups of neumes. For the sake of clarity, we have divided neume tables into three types: 1. Definitional, whereby neume shapes are given with their modern or square notation equivalences; 2. Translational, in which two scribal traditions are compared but neither is necessarily defined by reference to a modern rendition; 3. Descriptive, in which neumes are displayed with a focus on their full range of mutability and interpretation, depending on context. These categories roughly correspond to: 1. A unilingual dictionary, in which words are defined in a way that both clarifies their meaning and sets them apart from other words with similar meanings; 2. A bi-lingual dictionary, in which a word in one language is defined by way of a word or words in another language, but it is assumed that the reader understands the meaning of the words in the definition without those, too, having to be defined; 3. An encyclopaedia, in which a word is understood in its largest sense, as a concept, with attention paid to its history, context, applications, and permutations.

The sample of neume tables considered here is in no way exhaustive, but it did reveal some general trends about the way scholars have chosen to study

cessed May 2, 2017, <http://www.oxfordmusiconline.com.proxy1.lib.uwo.ca/subscriber/article/img/grove/music/F920586>, and the German music reference work, *Die Musik in Geschichte und Gegenwart: allgemeine Enzyklopädie der Musik*, (New York, 1994 – 2007) provide detailed introductory tables.

¹⁵ Mention is made of historical neume tables in Nancy PHILLIPS: *Notationen und Notationslehren von Boethius bis zum 12. Jahrhundert*, in: Michel Huglo – Charles M. Atkinson – Christian Meyer – Karlheinz Schlager – Nancy Phillips (eds.): *Die Lehre vom einstimmigen liturgischen Gesang*, (Geschichte der Musiktheorie, vol. 4), Darmstadt: Wissenschaftliche Buchgesellschaft, 2000 293-658, as well as Constantin FLOROS: *Universelle Neumenkunde. Die byzantinischen, slavischen und gregorianischen Tonfiguren und Formeln*, vol. 3, Kassel: Bärenreiter Verlag, 1970.

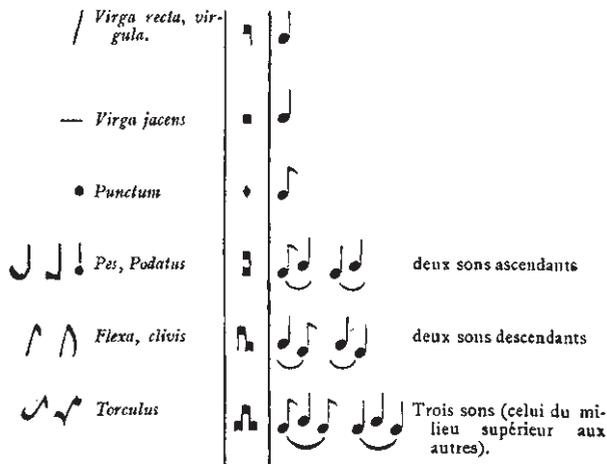


Figure 1: Théodore GÉROLD: *La Musique au Moyen Age*. Paris: Champion, 1932, 20.

neumes in the past century. As terminology has changed over the years, it is best to be clear here: this survey of neume tables also includes those tables¹⁶ which set out pitches written in square notation as ‘neumes’, but the focus of this study is on neume tables that are primarily concerned with neumes in *campo aperto*. **Appendix** lists all sources consulted in this study. Apart from well-known books dedicated to the subject such as Corbin’s *Die Neumen*,¹⁷ or Hiley’s *Western Plainchant*,¹⁸ prime candidates were the contents of periodicals such as *Études grégoriennes* and the scholarship prefacing many of the *Paléographie Musicale* facsimile volumes, as well as encyclopaedia such as *New Grove Dictionary of Music and Musicians* and its German counterpart, *Musik in Geschichte und Gegenwart* (MGG).

Usually, the definitional, or ‘dictionary’ type neume tables come either from the early days of Gregorian Semiology or they are featured in general music history reference texts. Théodore Gérold’s 1932 textbook entitled, *La Musique au Moyen Age*,¹⁹ contains a neume table of this kind, as shown in Figure 1. On the far left column, graphic representations of various neume shapes are given, sometimes two or three versions if one rendering cannot capture all the possibilities. Next comes the Latin name(s) for the sign which is then set off by a vertical line delineating the neume shape’s square note equivalent. To the right of the square note col-

¹⁶ See, for example, P. Dominicus JOHNER: *Neue Schule des Gregorianischen Chorals*, Regensburg: Pustet, 1906, 2.

¹⁷ Solange CORBIN: *Die Neumen*, *Palaeographie der Musik*, 1/3, Köln: A. Volk, 1977.

¹⁸ David HILEY: *Western Plainchant: a handbook*, Oxford: Oxford University Press, 1995.

¹⁹ Théodore GEROLD: *La Musique au Moyen Age*, Paris: Champion, 1932, 20-21.

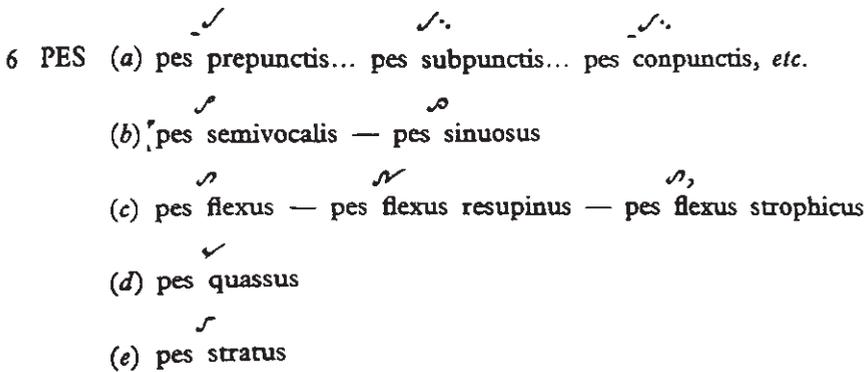


Figure 2: Michel HUGLO: Les noms des neumes et leur origine, *Études grégoriennes*, 1 (1954), 57.

um are modern notes in *campo aperto*, some even indicating rhythmic characteristics. In case the relative vertical positions of the modern notes was not clear, the right-most column describes the interval relationship between the neumes representing more than one pitch.

The first volume of *Études grégoriennes*, published in 1954, contains an article written by Michel Huglo concerning the origins of the names of neumes.²⁰ In it, he lists over fifteen medieval manuscripts in which musical notation itself is discussed, and neume names are given. He then sets out a comprehensive list of the neumes these medieval sources contain, dividing it into four categories: Primary, Derived, Ornamental, and Liquescent. Instead of offering a modern equivalent for each neume shape, Huglo simply connects the graphic shape to its Latin name on the assumption that the reader understands what is meant, musically, by each Latin neume name. Figure 2 shows the entry for the Pes, in which ten different versions of the basic neume sign are given with Latin names that differentiate between them. Interestingly, some of the names indicate aspects of performance, such as »pes semivocalis« or »pes sinuosus«, while others reference graphic features, such as »pes quassus«.

Other, more modern neume tables of this definitional type can be found in the introductions to two facsimiles in the *Paléographie Musicale* series, as well as textbooks on medieval music by Apel,²¹ Parrish,²² Caldwell,²³ Gleason and Becker,²⁴

²⁰ Michel HUGLO: Les noms des neumes et leur origine, *Études grégoriennes*, 1 (1954) 53-67.

²¹ Willi APEL: *Gregorian Chant*, Bloomington: Indiana University Press, 1966, 120.

²² Carl PARRISH: *The Notation of Medieval Music*, New York: Norton & Co., 1978, 6.

²³ John CALDWELL: *Medieval Music*, Bloomington: Indiana University Press, 1978, 24-25.

²⁴ Harold GLEASON – Warren BECKER: *Music in the Middle Ages and the Renaissance*, Bloomington: Indiana University Press, 1981, 14-15.

and Hiley,²⁵ Klöckner,²⁶ and Turco.²⁷ Each considers a different configuration of the known repertoire of early chant books and each displays the names and meanings of each notational sign (re-drawn for the table in the author's hand) in a slightly different way. Yet, for the purposes of familiarization with the repertoire as a whole, and to make the connection between the sign and its Latin name, these general tables are excellent.

The second type of neume table facilitates comparison. It is 'translational', as it makes connections between sets of neumes unified by scribal tradition, era, or performance practice. The analogy here is to a bilingual dictionary in which words in one language are defined in the words of a different language. The words on the page are connected through a common conception of semantic meaning, in the same way as differently written neume signs, representing various scribal conventions, are connected through a common musical meaning, even though that meaning is not necessarily given in modern notation at the same time. These translational neume tables are usually created to codify one notation tradition by comparing it to other, usually more well-known, notation traditions. Instead of simply setting out all the signs in the notation with their modern equivalents, the author uses comparison to make finer distinctions between the notation in question and those to which it is related. Of course, this requires that the reader be familiar with at least one of the scribal traditions involved in the comparison, in the same way as a bilingual dictionary is only useful to one who can read at least one of the languages it contains. Because of this presumed level of expertise, this type of neume table is generally found in more specialized sources, such as the foreword to a facsimile of a manuscript written in a particular notation. The 13th volume of *Paléographie Musicale*, for example, includes a hand-drawn table comparing 24 neume signs in the Aquitanian tradition to those in Chartres 47, an excerpt of which is shown in Figure 3, below. Here, the types of neumes are named and then divided into 'ordinary' and 'signs with rhythms' and within each of the two traditions compared, variants of each sign are given a number.

This kind of detailed comparison offers the researcher not only a glimpse into the kind of variation found between scribal traditions, but also the kind of variation allowed within the practice of rendering one neume sign in one tradition; in most of the quadrants of Figure 3 there are several different renditions of a sign that is referred to by only one Latin name. Expressing this kind of variation within one tradition as its own kind of 'translational' table, a researcher can compare basic signs to more complex ones, in the context of either the study of a single manu-

²⁵ David HILEY: *Western Plainchant: A Handbook*, Oxford: Clarendon Press, 1993, 352-361.

²⁶ Stefan KLÖCKNER: *Handbuch Gregorianik. Einführung in Geschichte, Theorie und Praxis des Gregorianischen Chorals*, Regensburg: ConBrio, 2009, 3 (new edition Regensburg, 2013).

²⁷ Alberto TURCO: *Il Canto Gregoriano*, vol. I: *Nozioni Fondamentali e Neumologia*, vol. II: *Toni e Modi*. Rome: Edizioni Torre D'Orfeo, 1996.

Noms	Neumes ordinaires		Neumes avec signes rythmiques			
	Aquit.	Chartres 47	Aquit.		Chartres 47	
Punctum			-		1 2 3	
Virga	1 2 / /	/	-		1 2 / t /	
Clivis ou Flexa	1 2 3 : : /	1 2 3 ~ ~ :	1 2 3 4 5 = : - / /		1 2 3 4 = / 7+ :	
Pes ou Podatus	1 2 3 ? / /	/ 2 - :	1 2 - /		1 2 3 4 - / / /	

Figure 3: Dom. A. MOCQUEREAU (ed.): *Paleographie Musicale*, vol. 13, Solesmes: 1971, 199.

	basic	liquescent		basic	liquescent
Punctum	.	•	Climacus	7 1: 7	7
Tractulus	-	-	Scandicus	7 7	7 7
Virga	1	1 + +	Acuasta	,	
Pes	1 1 1	1 1	Pes inflatilis	1 1	1 1
Clivis	1 1 1	1 1 1	Quilisma	1 1	1 1
Porrectus	1 1 1	1 1 1	Salicus	1 1 1	1 1
Toreculus	1 1 1	1	Isolated Oriscus	1	

Figure 4: Matthew PEATTIE: *Constructing a Typeface of Medieval Neumatic Notation: Challenges of Representation and Translation*, in: *Chant and Culture: Proceedings of the conference of the Gregorian Institute of Canada*, Lions Bay, B.C.: Institute of Medieval Music, 2014, 247.

script or a large-scale exploration of the capabilities and limitations of graphic expression, in general. In Matthew Peattie’s article,²⁸ for example, »Constructing a Typeface of Medieval Neumatic Notation: Challenges of Representation and Translation«, he presents a neume table to set out the differences between basic and liquescent neumes in the Beneventan scribal tradition (see Figure 4).

²⁸ Matthew PEATTIE: *Constructing a Typeface of Medieval Neumatic Notation: Challenges of Representation and Translations*, in: *Chant and Culture: Proceedings of the conference of the Gregorian Institute of Canada*, University of British Columbia, August 6–9, 2013, Lions Bay, BC: Institute of Medieval Music, 2014, 245-262.

n.º cad. e.º cad.	L SG E			n.º cad. e.º cad.	L SG E			n.º cad. e.º cad.	L SG E			n.º cad. e.º cad.	L SG E		
	Cp1, 2, a...				Cp4, 5, a...				Cp6, 7, a...				Cp8, 9, a...		
11	♩	♩	♩	33 †	♩	♩	♩	65 †	♩	♩	♩	95 +	♩	♩	♩
2+	♩	♩	♩	34	♩	♩	♩	66 †	♩	♩	♩	96 †	♩	♩	♩
3 †	♩	♩	♩	35	♩	♩	♩	67 †	♩	♩	♩	97 +	♩	♩	♩
4 †	♩	♩	♩	36 †	♩	♩	♩	68 †	♩	♩	♩	98 †	♩	♩	♩
5 †	♩	♩	♩	37 †	♩	♩	♩	69 †	♩	♩	♩	99 +	♩	♩	♩
6 †	♩	♩	♩	38 +	♩	♩	♩	70 †	♩	♩	♩	100 †	♩	♩	♩
7 †	♩	♩	♩	39 †	♩	♩	♩	71 †	♩	♩	♩	101 †	♩	♩	♩
8 †	♩	♩	♩	40 †	♩	♩	♩	72 †	♩	♩	♩	102 †	♩	♩	♩
9 †	♩	♩	♩	41 †	♩	♩	♩	73 †	♩	♩	♩	103 †	♩	♩	♩
10 †	♩	♩	♩	42 †	♩	♩	♩	74 †	♩	♩	♩	104 †	♩	♩	♩
11 †	♩	♩	♩	43 †	♩	♩	♩	75 †	♩	♩	♩	105 +	♩	♩	♩
12 †	♩	♩	♩	44 †	♩	♩	♩	76 †	♩	♩	♩	106 †	♩	♩	♩
...	♩	♩	♩	45 †	♩	♩	♩	77 †	♩	♩	♩	107 †	♩	♩	♩
13 †	♩	♩	♩	46 †	♩	♩	♩	78 †	♩	♩	♩	108 +	♩	♩	♩
14 †	♩	♩	♩	47 †	♩	♩	♩	79 †	♩	♩	♩	109 †	♩	♩	♩
15 †	♩	♩	♩	48 +	♩	♩	♩	80 †	♩	♩	♩	110 †	♩	♩	♩
16 †	♩	♩	♩	49 †	♩	♩	♩	81 †	♩	♩	♩	111 †	♩	♩	♩
17 †	♩	♩	♩	50 †	♩	♩	♩	82 †	♩	♩	♩	112 +	♩	♩	♩
18 †	♩	♩	♩	51 +	♩	♩	♩	83 †	♩	♩	♩	113 +	♩	♩	♩
19 †	♩	♩	♩	52 +	♩	♩	♩	84 †	♩	♩	♩	114	♩	♩	♩
20 †	♩	♩	♩	53	♩	♩	♩	85 †	♩	♩	♩	115 †	♩	♩	♩
21 †	♩	♩	♩	54 †	♩	♩	♩	86 †	♩	♩	♩	116 †	♩	♩	♩
22 †	♩	♩	♩	...	♩	♩	♩	87 †	♩	♩	♩	117 +	♩	♩	♩
23 †	♩	♩	♩	55 †	♩	♩	♩	88 †	♩	♩	♩	118 +	♩	♩	♩
24 †	♩	♩	♩	56 †	♩	♩	♩	89 †	♩	♩	♩	119 †	♩	♩	♩
25 †	♩	♩	♩	57 †	♩	♩	♩	90 †	♩	♩	♩	120 †	♩	♩	♩
26 †	♩	♩	♩	58 †	♩	♩	♩	91 †	♩	♩	♩	121 +	♩	♩	♩
27 †	♩	♩	♩	59 †	♩	♩	♩	92 †	♩	♩	♩	122 +	♩	♩	♩
28 †	♩	♩	♩	60 †	♩	♩	♩	93 +	♩	♩	♩	123 +	♩	♩	♩
29 †	♩	♩	♩	61 †	♩	♩	♩	...	♩	♩	♩	124 +	♩	♩	♩
...	♩	♩	♩	62 †	♩	♩	♩	94 +	♩	♩	♩	125 †	♩	♩	♩
30 †	♩	♩	♩	...	♩	♩	♩	95 +	♩	♩	♩	126 †	♩	♩	♩
31 †	♩	♩	♩	...	♩	♩	♩	96 +	♩	♩	♩	127 †	♩	♩	♩
32 †	♩	♩	♩	...	♩	♩	♩	97 +	♩	♩	♩	128 +	♩	♩	♩

Figure 5: Nino ALBAROSA: Le torculus en fin de neume cadential, *Études grégoriennes*, 23 (1989), 92.

A variation on the theme of translational tables is the table in which only certain neumes, and the contexts in which they appear, become the primary focus. In this type of neume table, it is not the meaning of the neume shape itself that is given, but rather, the larger notational landscape that is considered as a key factor in their musical meaning. Often, the use of a particular neume in a specific place in a chant is interesting to compare across scribal traditions, and this is exhibited in a neume table such as the one shown in Figure 5. Here, Nino Albarosa examines the torculus found at the end of over one hundred cadence gestures in Laon 239, St. Gall 359, and Einsiedeln 121 and compares each instance.

As the list in **Appendix** shows, neume tables that offer a ‘translation’ of one system of notation to another seem to have reached an apex of sorts in the mid-20th century, when the focus of scholars had generally shifted from discovering the meaning of the signs themselves to exploring the extent of the variations between notation traditions. Of course, comparing neumes within and between scribal conventions is an on-going pursuit, and this type of table is not limited to one period in the history of the study of chant notations.

The final type of neume table discussed here is one in which neumes are taken as the building blocks for whole phrases or gestures, and understood as identifiers for certain scribal traditions on a broader scale. We might call this type of table ‘encyclopaedic’, in that they place neumes in their larger context and consider them not only in terms of what they represent, musically, but how they function as part of a larger melody. The type of neume table necessary for this perspective is one in which the conceptual categories of neume notation is clearly depicted. In Luigi Agustoni’s 1963 book,²⁹ *Gregorianischer Choral*, he shows the hierarchical divisions inherent in neumes in his tree diagram, reproduced in Figure 6, below. Here, he groups certain types of neumes together, according to their functions in the larger, melodic whole. In this way, Agustoni divides his discussion of notation (as seen in his references to book chapters, in the table itself). Understood as groups of signs with particular characteristics that unify them and define their function, the shape of the individual rendering of the neumes themselves are no longer the focus. Used as graphic components in expressing longer sections of chants, encyclopedic neume tables reveal larger cultural ‘readings’ of melodic phrases. Many studies published in *Études grégoriennes* in the 1970s and 1980s contain this type of neume table, with whole pages divided into small boxes wherein opening gestures or cadential figures are written out and compared to other such gestures. Figure 7 is a representative section of the extensive table given in Dom Eugène Cardine’s study of the torculus neume in the Mont-Renaud tradition.

In this case, Cardine has given a basic version of the gesture in square notation, followed by his own hand-drawn representations of how this gesture ap-

²⁹ Luigi AGUSTONI: *Gregorianischer Choral*, Freiburg: Herder, 1963.

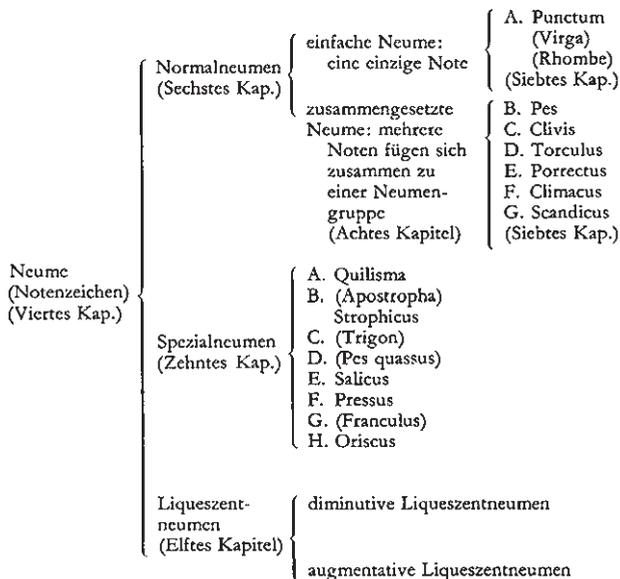


Figure 6: Luigi AGUSTONI: *Gregorianischer Choral*, Freiburg: Herder, 1963, 44.

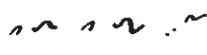
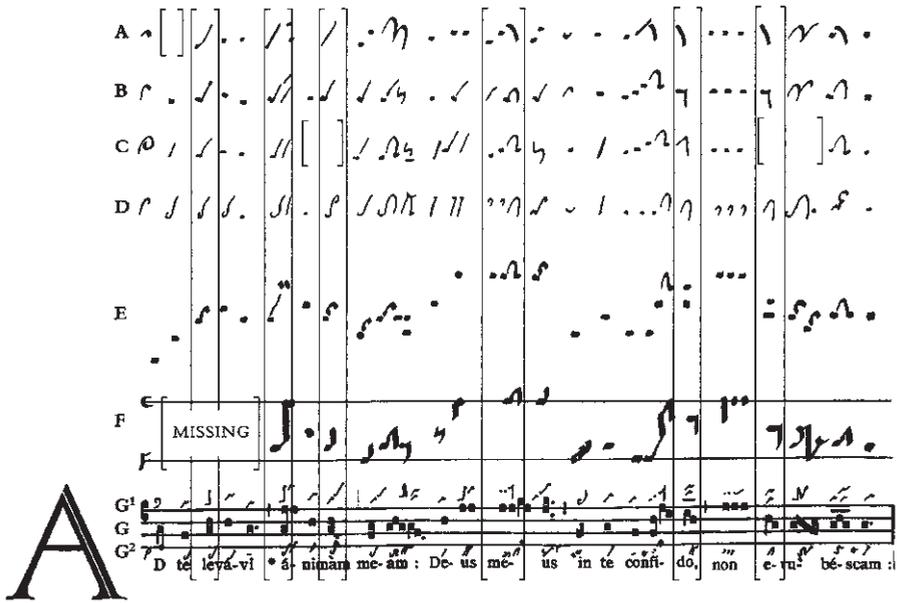
tableau 1	
 1. GT 289/3 74	 RG Propitius esto V honorem 125
 2. GT 486/5 44	 RG Ecce sacerdos V conservaret 44
 3. GT 279/7 140	 RG Ego dixi V... egenum 314
 4. GT 477/2 127	 RG Iustus [non cont.] V... semen eius 284

Figure 7: Dom Eugène CARDINE: *Les Torculus du Mont-Renaud*, *Études grégoriennes*, 24 (1992), 178.



A. Paleofrankish (Düsseldorf D 1); B. Bretonic (Angers 91); C. French (Chartres 47); D. St. Gall (St. Gall 339); E. Aquitanian (Paris 903); F. Beneventan (Benevento 34)—and as it appears in the *Graduale triplex*: G¹ (Laon 239); and G² (St. Gall 376)

Figure 8: Charles ATKINSON: *The Critical Nexus: Tone-System, Mode, and Notation in Early Medieval Music*, Oxford: Oxford University Press, 2009, 112-113.

pears in various chants. It is a short step from this kind of display to a complete parallel transcription of a chant, in which several versions of a single melody are stacked vertically for ease of comparison, while preserving the musical context of the chant in question. Atkinson's example of a parallel transcription of *Ad te levavi*, in his book, *The Critical Nexus: Tone-System, Mode, and Notation in Early Medieval Music*, serves here as a fine example of the conceptual overlap between neume tables and parallel transcriptions.³⁰ Read vertically, Figure 8 could function like a 'translational' neume table, as the eye considers the rendering of each neume sign in the various notations represented. Read horizontally, we gain more of a sense of musical context and begin to see how these signs are indicative of an already-understood aural reality for the medieval singers who used them. If we connect the neume signs and the square notation on the staff, we might read this transcription as a 'definitional' neume table, where information about interval direction and pitch number is transferred onto one kind of notation from another.

³⁰ Charles ATKINSON: *The Critical Nexus: Tone-System, Mode, and Notation in Early Medieval Music*, Oxford: Oxford University Press, 2009.

Neume Tables, a methodology

Whether definitional, translational, or encyclopedic, neume tables are constructed based on certain assumptions about the way they will be used. The richness of detail they contain has been indispensable for the continued growth and evolution of chant studies, but as circumstances surrounding them change, it is time to take a closer look at these assumptions. Perhaps the most significant influence the presence of neume tables has had over the past century of scholarship is the unwitting canonization of some notations and the marginalization of others. The first scribal tradition to be thoroughly studied was that of the Saint Gall scriptorium; this type of notation is described with 'definitional' neume tables and is then used as the tradition to which to compare other notations. French and German notation traditions become the mainstay of the field; these are the neume shapes that nudge their way towards being mental standard for the Latin names given to them. We can even see this residual centrality in the arrangement of the general neume tables in encyclopedias, such as the *New Grove* or the *MGG*, in which the example of Saint Gall neumes comes first and is the most complete of all the other notations listed in the tables.

The best and most natural use for a neume table is as a guide or reference when transcribing chant (from a source directly connected to that table, specifically), or editing a chant in modern notation by inserting information implied by certain signs. A neume table developed for a particular book acts as a kind of code-cracking device, and as such, is quite useful. It is when neume tables separate from their original contexts and become frames of objective reference in themselves – a kind of notational 'periodic table of elements' – that it becomes imperative that we consider their limitations as well as their benefits. After all, the medieval books we now study were not written with our neume tables for reference, and the more we look for everything to fit nicely into our categories, the more exceptions we seem to find. This is, of course, the plague of transcriptions of medieval and Renaissance musical notation more generally; Margaret Bent, in her article concerning the editing of early music, asserts that, »we shall have taken a large step forward when, as editors, we recognize that we are translating, not merely transcribing, into modern notation, and that what we present is subject to all the hazards of interpretation and loss that beset a linguistic translation.«³¹

One problematic assumption about neume tables is their completeness. Perhaps, for some traditions, scholars truly have uncovered all there is to know, but for most others, a neume table represents what has been determined to date, not an exhaustive list of possibilities. One can only describe and categorize that which is already known; consequently, the neume tables containing examples of notation

³¹ Margaret BENT: *Editing Early Music: The Dilemma of Translation*, *Early Music*, 22 (1994) 3, 391.

only recently rediscovered will necessarily be shorter and less detailed than a neume table for which many exemplars have been thoroughly studied. The hope is that, as scholarship branches out, the lacunae are filled and missing details are sketched in, but we should never lose sight of the idea that these tables are a work in process. If they can be compared once more to a dictionary of sorts, then they must be dictionaries containing only the words in the books we have actually read.

While most neume tables contain information about the meaning and function of neumes that has been proven correct across a relatively wide spectrum of scholarship that relies on them, we should also remember that our understanding is based on the findings of several individual scholars' work and not on some objective list of rules and definitions passed through generations in an unbroken chain. Determining the meanings of specific neume signs requires looking for every occurrence of that sign in the set of sources in which it is expected to be found, noting how it is used each time, and then extrapolating from individual uses what its function might be. In some cases, the neume might be contextualized by certain other neumes, in others, it could be connected to the chant text with which it is associated. Discovering a new or inexplicable use for a neume requires changing the old definitions. For some neume signs, such as the quilisma, this kind of painstaking detective work has yet to reveal reasonably certain conclusions, leaving those 'modern notation equivalent' sections blank in definitional neume tables. The problem is the same as the issue of completeness. We rely solely on the information we happen to inherit from previous generations of scholars, and therefore our knowledge base is coloured and shaped by their interests. Given the scope of that task, completeness is impossible for the individual researcher. Even those studies of individual neumes in specific scribal traditions, such as the analyses of the *salicus* in the Saint Gall, and Laon scripts, in *Études grégoriennes* vols. 14 and 16 respectively, offer conclusions only about its use in those two locations. How securely can we extrapolate what we find in one book to other books in the same scribal tradition? To distantly-related traditions?

Finally, there is the question of scale. Through different methods of calculation, both Bruno Stäblein and, later, Andrew Hughes calculated that at least 30 million liturgical books were produced during the four or five centuries encompassed by our term 'Middle Ages' and that over 30,000 are extant today.³² As Andrew Hughes argued in 2004, »How many such books have been adequately described by a competent authority? Five percent? Generalizations about the liturgy made from five percent of the repertory will hardly be convincing. To proceed with liturgical research that is appropriately placed in its context, we must at least

³² Bruno STÄBLEIN: *Schriftbild der einstimmigen Musik*, Musikgeschichte in Bildern, III/4, Leipzig: Deutscher Verlag für Musik, 1975, 102, and Andrew HUGHES: Liturgical Books: In Order to Order, in: David Hiley (ed.): *Die Erschliessung der Quellen des mittelalterlichen liturgischen Gesangs*, Wiesbaden: Harrasowitz, 2004, 141.

know what is available.«³³ The same is true of research on musical notation, of course, except here the numbers are even larger. How many neumes are in Hartker's Antiphoner, Saint Gallen 390 – 391? No one knows the exact number, but rough calculations put it at around 230,500. How many of these are the two-hooked quilisma, and how many the three-hooked quilisma? How many of these form patterns that would have been understood (or intuited) by medieval singers but which we have yet to even recognize? In one of the last articles Dom Cardine ever wrote, he warned of the likelihood of losing oneself in the management of details and forgetting the larger picture: »Le danger qui nous guette est trop connu: c'est de se perdre dans tous les détails identifiés et appris avec fatigue, et d'oublier l'ensemble.«³⁴ Realizing the enormity of the exercise, we look for a way to build on the foundation that traditional neume tables have provided, using the technological tools now available.

Morphology and Neume Tables

It might seem naïve to imagine a world in which all notational traditions are explored equally, observations about neume function are completely accurate, and all extant manuscripts intensely studied. Naïve, that is, until we remember that we must no longer work alone, or by hand, as previous generations of scholars did. By leveraging the innovations of our age, it is possible to accelerate the rate at which the study of medieval musical manuscripts progresses. To borrow from the terminology of Linguistics, we are ready now to create not a dictionary, but a *morphology* for neumes; we are in a position now to be able to study not only what each sign means, but how they are formed, and what their relationships are to other neumes and to the chant text they set. The Optical Neume Recognition project places itself at the nexus of technological development and musicological curiosity, bringing scholars with different expertise together to improve our methods and sharpen our insights into music written one thousand years ago. The idea is to use computer technology to help us change the landscape of chant studies itself — increase the number, and degree of detail, of the sources available, as well as the speed and accuracy with which our questions about that landscape can be answered. There are two key elements in this: digital imaging software and optical music recognition (OMR). The number of digital images of manuscripts that are now online as part of library initiatives around the world, is increasing every day; software that can 'read' and then encode this information must keep up, if we are to take full advantage of the richness now available in our field. At present, OMR is efficient at understanding modern printed musical notation, but processing

³³ HUGHES: Liturgical Books, 141-142.

³⁴ Eugène CARDINE: Les Limites de la Sémiologie, *Études grégoriennes*, XXIII (1989), 9.

hand-written notations on historical documents presents real challenges. The Optical Neume Recognition project directly tackles the earliest Western musical notation still left to us, by developing software that can identify and process these thousand-year-old neumes in ‘classifiers’ and then encode the musical information inherent in the neumes in a standardized way. In practical terms, this project involves teaching the computer to classify neume shapes and allocate certain types of musical directives to them, just as a traditional neume table does. The only difference is that of scale.

Optical Neume Recognition

The manuscript on which the Optical Neume Recognition project focuses currently is Hartker’s antiphoner (Sang. Cod. 390 / 391), a completely notated source from around the turn of the 11th century, representing the quintessential Saint Gall notation tradition. This antiphoner is a well-studied source, with a facsimile edition,³⁵ extensive neume tables, and articles written about the scribal hands represented therein.³⁶ We chose this source as proof-of-concept: existing theories about neume interpretations can now be tested empirically on hundreds of thousands of individual neumes to see if they hold up. We can track — and compare — the patterns, alterations, and pairing of neumes to syllables, quickly and accurately. But the ‘neume table’ developed for the Optical Neume Recognition project need not be discarded once our analysis of this particular book is complete. Our aim is to create a neume table that is widely-applicable enough to encompass all kinds of medieval neumes, so that the field of analysis is as open as possible. This means being able to compare neume placement and function not only throughout one book (at approximately 230,000 neumes) but between books and even between scribal traditions. Therefore, the technology behind these comparisons must be capable of working with literally billions of neumes, and we must be ready to ask the questions that, until now, have been impossible to answer. It is this technology that allows us to build an understanding of neume morphology.

To be able to identify the neumes on a digital image of a manuscript folio, the classifier works with a human musicologist to begin the sorting process. The musicologist selects, from the image itself, some representatives of each neume and then submits this information to the software program. The program will then look for more instances of every neume for which it has a category, and arrange other signs it detects from most- to least-similar, so that the human can ‘teach’ it in

³⁵ Jacques FORGER (ed.): *Antiphonaire de Hartker Manuscrits de Saint-Gall 390-391*, *Paléographie musicale*, 21 (1992).

³⁶ See, for example, Kees POWDEROIJEN and Ike DE LOOS: *Wer ist Hartker? Die Entstehung des Hartkerischen Antiphonars*, *Beiträge zur Gregorianik*, 47(2009), 67-86.

more detail, resubmit that information, and repeat the process until all neume signs are accounted for. What the software ‘learns’ about one folio image will be transferred to all subsequent images. The advantage to this system is that the neumes remain exactly as they are in the manuscript; no attempt has been made to re-draw them, or make them fit a standard rendering. This allows for the kind of variance that exists – or might exist – in scribal practice to be represented and maintained in the analysis. Once the classifier has produced an exhaustive list of all neumes found in the manuscript, the neume meanings themselves must be added. In the case of the Optical Neume Recognition project, it was determined that the best way of expressing that meaning is in the musical XML called the ‘Music Encoding Initiative’ (MEI). As a computer language, the grammar of MEI optimizes descriptions of musical notations and the types of attributes allowed in the description. It is the set of best practices that acts as a translation between a musician’s understanding of notation and a computer’s ability to represent it.

The neume table forming the basis of the Optical Neume Recognition project must be compatible with MEI’s hierarchical descriptions, in order to be the connective tissue between the classifier’s list and any musical comprehensibility. Figure 9 shows a representative sample of the project’s neume table which, in its entirety, depicts approximately 400 neumes. Just like neume tables of generations past, the first column contains an image of the neume, and the second gives its Latin name. The third column indicates the number of pitches indicated by the neume – this is where we begin to depart from traditional neume tables, and where the structure of MEI description takes priority. For the MEI to work, it needs to express the meaning of each neume as a group of a certain number of pitches, each with characteristics related to each other. In Figure 9: A selection of the neume table developed as part of the Optical Neume Recognition Project we see 10 versions of the basic neume, *pes*. In the versions that do not include a third, liquescent pitch at the end, the number of pitches expressed by the *pes* is 2. The chart then proceeds chronologically, describing the first pitch, second pitch, third pitch, etc. (The entire neume table goes up to 10 pitches, but for ease of viewing, only the columns involved in the three pitches making up the liquescent *pes* have been included here.) For each pitch, three different kinds of information is required: its directional relationship to the previous pitch (N = neutral; H = higher; L = lower; S = same);³⁷ the presence of any modifications to the rendering of that pitch itself, as shown in the neume shape; and the type of connection to the next pitch. If there is no modification, or no special type of connection, then these are left blank.

At present, we have identified 13 different kinds of modifications, shown in Figure 10.

³⁷ This system is used, and was generously shared with our project, by Emma HORNBY et al. in their work on Old Hispanic neumes. See: The Old Hispanic Office, <http://www.bristol.ac.uk/arts/research/projects/theoldhispanicoffice.html>

- w - wavy
- b - curve anticlockwise
- c - curved clockwise
- a - angled
- e - episema
- f - flat
- j - jagged
- l - liquescent
- x - extended
- y - diagonal upwards, to the right
- k - diagonal downwards, to the right
- q2 - quilisma: 2 loops
- q3 - quilisma: 3 loops

Figure 9: A selection of the neume table developed as part of the Optical Neume Recognition Project

Neume Image	Neume Name	Num. of pitches	PITCH 1	PITCH 1	PITCH 1	PITCH 2	PITCH 2	PITCH 2	PITCH 3	PITCH 3
			R to prev	Modif	Connect to pitch 2	R to prev	Modif	Connect to pitch 3	R to prev	Modif
	Pes rotundus	2	N			H			---	---
	Pes rotundus episema	2	N			H	e		---	---
	Pes rotundus liquescent curved	3	N			H	---		L	lc
	Pes rotundus liquescent curved episema	3	N			H	e		L	lc
	Pes quadratus angled	2	N	a		H	---		---	---
	Pes quadratus angled episema	2	N	a		H	e		---	---
	Pes quadratus angled liquescent	3	N	a		H	---		L	lc
	Pes quadratus angled liquescent episema	3	N	a		H	e		L	lc
	Pes quassus 1	2	N	w		H	---		---	---
	Pes quassus 2	2	N	wa		H	---		---	---

Figure 10: Types of modifications to each pitch as registered in the Optical Neume Recognition neume table

The letters used for abbreviation to indicate these modifications are arbitrary; we tried to make them as intuitive as possible, but some cases have better fits than others. The only requirement from an MEI perspective is that every row in the table be different, beginning with the number of pitches. In fact, attaching musical meaning to the shapes identified by the classifier has nothing to do with the neume name at all, and inclusion of the neume shape in the table is merely to confirm its match to the classifier list. Understanding this frees us from some of the restrictions of traditional neume tables; we can express strings of neumes that are understood as belonging to the same musical, conceptual unit, without having to come up with complicated Latin names for them, yet still express them in the neume table, allowing the classifier to isolate specific cadences, turns of phrase, etc. By indicating that the connection between pitches is 'g' = gapped instead of the default, smooth connection, the computer can understand that two pen-strokes that are not touching still belong together. The allocation of relative pitch (H = higher) rather than an absolute pitch represented with a letter name, allows us to preserve information about melodic outline and musical gesture even in neume traditions that do not represent pitches on a staff, in the hopes that one day the MEI representing both pitched and unpitched notations will be compared by contour, revealing further interesting matches and deviations.

While constructed with the forms of traditional neume tables in mind, the Optical Neume Recognition neume table is more an attempt at codifying exactly what the singer understands when reading neumes in a computable way. It is one thing to look at a string of neumes and think one understands what is being expressed, and a very different thing to break this understanding down into steps that software can complete. Yet, deconstructing a challenge into computable and non-computable parts is a very good way to comprehend what sort of problem it is, in the first place. It also reveals unconscious assumptions scholars have about how neumes relate to the chant overall, about what sorts of decisions were made by medieval scribes, and by those who interpreted the notation through the centuries. By isolating information about each neume that can be repeatedly demonstrated as 'true' and refraining from further speculation, we harness the power of the vast amount of data now available to us to reveal tendencies we could not recognize, confirm suspicions we did have, or refute theories that do not prove true when scaled up. The neume table has now become an important part of the newest processes in uniting our digital capabilities and our understanding across wide ranges of notation traditions and scribal habits to form a comprehensive and useful morphology.

APPENDIX

A Morphology of Medieval Notations in the Optical Neume Recognition Project

Type 1	Type 2	Type 3
Agustoni 1963	Agustoni/Göschl 1987	Agustoni/Göschl 1987
Agustoni et al. 1993	Albarosa 1989	Atkinson 2009
Apel 1966	Aubert 2014	Aubert 2015
Caldwell 1978	Balducci 1979	Behrendt 2013
Cardine 1970	Boudeau 2012	Brockett 1968
Gérolde 1932	Brockett 1968	Cardine 1968
Gleason and Becker 1981	Cazaux-Kowalski 2012	Cardine 2003
Hiley 2009	Colette 2012	Cullin 1989
Hoppin 1978	Haggh 2007	Fischer 1986
Huglo 1954	Hiley 1993	Fischer 1995
Johner 1924	Hughes 1989	Fischer 1995
Kelly 2015	Kelly 2009	Fischer 1996
Parrish 1978	Maesson 2013	Fischer 1997
Pothier 1881	Nelson 1996	Fischer 1998
Read 1969	Peattie 2014	Fischer 1999
Wagner 1930	Phillips 2000	Floros 1970
	Randel 1969	Floros 1980
	Reese 1940	Hiley 1993
	Riemann 1878	Klößner 2000
	Rumphorst 1980	Klößner 2009
		Kurris 1971
		Kurris 1997
		Le Roux 1963
		Levy 1998
		Maesson 2013
		McEwan 2005
		Pfisterer 2006-07
		Phillips 2000
		Picone 1977
		Ponchelet 1973
		Riemann 1878
		Saulnier 1992

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*Sažetak***MORFOLOGIJA SREDNJOVJEKOVNIH ZAPISA U PROJEKTU OPTIČKO
PREPOZNAVANJE NEUMA (OPTICAL NEUME RECOGNITION PROJECT)**

Proučavanje srednjovjekovne notacije ovisi o uspješnoj kategorizaciji individualnih znakova u svrhu omogućavanja opsežnog razumijevanja njihova glazbenog značenja. Tijekom prošloga stoljeća, istraživači napjeva razvili su nekoliko različitih tabela neuma koje razvrstavaju i kontekstualiziraju neume po njihovu grafičkomu tipu, kronologiji ili pisarskoj tradiciji. Neke tabele neuma sadrže duže nizove neuma koje povezuju određene pisarske konvencije s izvođačkim tradicijama. Tijek razvoja tabela neuma prikazuje i samu povijest istraživanja rane notacije te nam otkriva razvoj interesa i težnja istraživača koji su ih kreirali. To je također poslužilo kao priprema za najnoviju uporabu tabela kao referentne točke u računalnim programima za analizu dokumenata koji se koriste kod digitalnih slika srednjovjekovnih rukopisa. Sada, umjesto da predstavlja statičan popis izoliranih znakova, tabelu neuma možemo shvatiti kao odraz notacijske raznolikosti i nijansa između stotina tisuća neuma prisutnih u svakoj knjizi liturgijskih napjeva. Na ovoj razini, tabele neuma omogućuju istraživačima razumijevanje korištenja srednjovjekovnih neuma na isti način kao što lingvisti razumiju morfologiju riječi. Ovaj članak predstavlja principe na kojima je razvijena ova nova vrsta tabela neuma i sugerira načine na koje bi ovaj novi modus razmišljanja mogao unaprijediti disciplinu u budućnosti.