

# A Typology for Cipher Key Instructions in Early Modern Times

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## Abstract

We present an empirical study on instructions found in historical cipher keys dating back to early modern times in Europe. The study reveals that instructions in historical cipher keys are prevalent, covering a wide range of themes related to the practical application of ciphers. These include general information about the structure or usage of the cipher key, as well as specific instructions on their application. Being a hitherto neglected genre, these texts provide insight into the practice of cryptographic operations.

## 1 Introduction

Historical cipher keys have been studied empirically and during the past years rather extensively, as evidenced by works such as (Rockinger, 1892; Meister, 1902; Meister, 1906; Kahn, 1996; Láng, 2018; Lasry et al., 2020; Megyesi et al., 2024; Megyesi et al., 2022), along with the examination of ciphertexts. Despite this attention, our understanding of how cipher keys were practically applied and used remains limited. This gap in knowledge arises because ciphertexts and cipher keys are seldom stored together in archives and libraries, posing challenges to researching key usage practices. To address this issue, one approach is to investigate the instructions written by the creators of cipher keys.

In this paper, we aim to explore whether and how instructions were utilized in historical cipher keys, and what information they contained about their structure, application, and usage. The following questions guide our inquiry:

- How prevalent are instructions in historical cipher keys from early modern Europe?

- What types of information do instructions in historical cipher keys encompass?
- What insights can we gain about the practical usage of cipher keys from these instructions?

In the subsequent section, we will review prior work on the subject. Following that, we will define the term "instructions" and outline our investigation and methodology. We will then present the characteristics of the instructions found in historical cipher keys, accompanied by illustrative examples, and discuss our discoveries. Finally, we will conclude the paper and identify further research directions.

## 2 Previous Work on Instructions in Keys

Instructions such as notes, explanations, and cipher rules are widely known among crypto-historians studying the early modern era, yet explicit secondary literature on them is scarce. Alois Meister called attention to the importance of cipher instructions given to individual envoys already in his earlier book on the beginnings of diplomatic cryptography (Meister, 1902), and cited a variety of them in his second book as sources for the actual application of ciphers (Meister, 1906). He added that these brief written texts attached to the ciphertexts were probably accompanied by oral explanations from the cipher secretary (p. 59).

In the 120 years following Meister's works, instructions were not systematically studied as a genre but as individual examples that facilitate understanding a specific, unconventional key (Láng, 2022). Lately, Camille Desenclos devoted more systematic attention to how the 16th-century scribes in France acquired cryptographic knowledge. In her unpublished study, she is particularly interested in the actual practice using the instructions as precious sources regarding the practical reality of cryptography (Desenclos, 2023).

### 3 Instructions

Before we explain how we investigate instructions in cipher keys, we need to comment on the actual term "instruction" as it allows for various interpretations.

By an instruction we usually mean a set of directions or orders given to guide someone in performing a task or carrying out a particular action. It typically provides step-by-step information or guidance on how to achieve a specific goal or complete a task. Instructions are designed to be clear, concise, and informative, helping the recipient understand what needs to be done and how to do it optimally. Instructions can be found in various contexts, such as manuals, guides, procedures, or verbal communication, and they play a crucial role in conveying information and facilitating understanding for effective execution of tasks.

In our study, we adopt a broad interpretation of the term in the context of historical cipher keys. We focus on identifying descriptions within keys that elucidate the operational use of a cipher key, encompassing both the key's content and intended application in clear text, regardless of the language. Moreover, instructions are contemporaneous with the keys they accompany and, just like the keys themselves, are oftentimes anonymous. Our inquiry remained open to the length of the instruction, ranging from a single word to several pages of documents.

Notably, instructions and explanations occurring in the cipher treatises of named cryptographers are certainly relevant but not the subject of our present inquiry.

### 4 Method

Our study originates from an examination of a sample of cipher keys to understand what was encoded in historical cipher keys and how this was done (Megyesi et al., 2024). We use the same set of cipher keys, consisting of 1610 keys, all sourced from the DECODE database (Héder and Megyesi, 2022). We identified and extracted cipher keys containing instructions, resulting in a total set of 235 cipher keys. This means that 15% of the keys contained some kind of instructions, which is not a result of representative research, but we believe it gives a realistic image of how many cipher keys survived together with some instructional notes. The keys originate from a wide range of geographic areas and time periods, as illustrated

in Figures 1 and 2.

Each key in the sample was manually analyzed and cross-validated in cases where there was ambiguity. The parameters that we marked were length (short or long), the language of the cleartext (e.g., Latin, French, English, German, Spanish), and the content described as free text. The content description encompassed details about the usage of individual code elements and their application, such as explanations of how to apply nullities. It also incorporated notes about the interpretation of the cipher key table or the key's application in various contexts. On the basis of these parameters and descriptions, we categorized the types of instructions and their functions. Below, we provide a summary of our findings.

## 5 Types of Instructions

### 5.1 Structural Information

The great majority of cipher keys feature concise and short explanations of various functions represented within the key. These explanations often include section titles such as "Ad scribendum" (to write) and "Ad legendum" (to read), as seen in two co-stored keys, depicted in parts in Figure 3. The titles indicate that the key information presented in the "Ad scribendum" part shall be used for encryption while the section "Ad legendum" shall be used for decryption. The plaintext elements and the code elements are sorted in reversed order in the two sections facilitating the respective cryptographic operation. As illustrated in Figure 3, the code elements follow the order of the plaintext elements (alphabet letters in Figure 3) in the "Ad scribendum" section, and vice versa, the plaintext elements are arranged according to the code elements' order in the "Ad legendum" section (numerical order in Figure 3). Other titles indicating the same function occurring in our material are "Zum Chiffriren" vs. "Zum Dechiffriren", "pour Chiffre" vs. "pour Dechifre".

Structural information given as titles may also include explanation of specific types of code elements, such as nullities, cancellation signs, days of the month, or grammatical categories like "Signa Casuum" (signs of cases) and "Numeri nihil significantes" (numbers of no significance), as shown in Figure 4.

Additionally, it is common to find descriptions of specific sections of the cipher key table, providing clarity on the content of the key. An illustrative

Number of documents by century

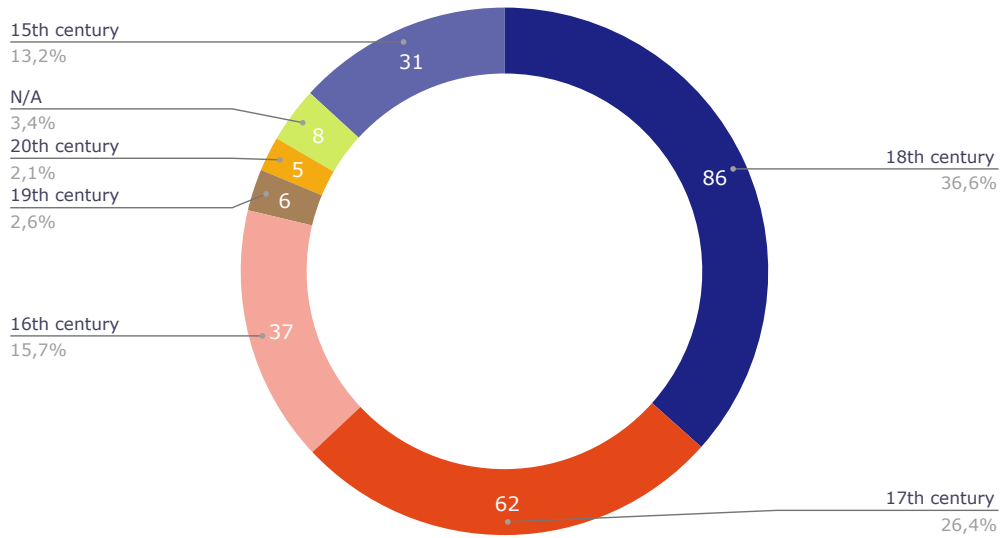


Figure 1: Time period of the key sample containing instructions

Number of documents by current location

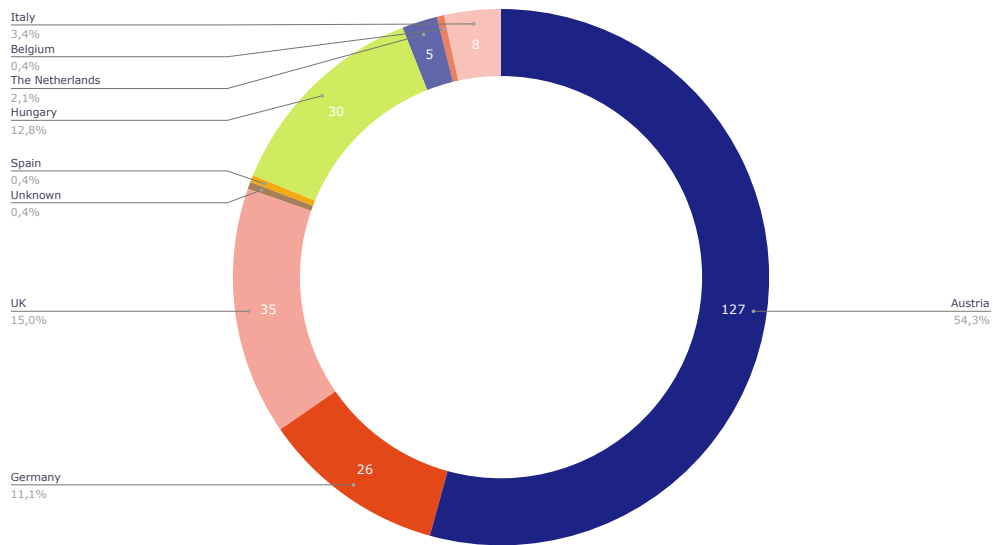


Figure 2: Geographic areas of the key sample containing instructions

example is presented in Figure 5.

## 5.2 Information about Code Elements

Typically, cipher keys also contain information about various groups of code elements with certain functions such as code elements for nullities, cancellation signs, double plaintext letters, punctuation marks or paragraph markers, to mention a few. An example of such a cipher key is illustrated

in Figure 6 containing the cleartext "Nulles 9, 99, 999; deux points 909 - ad lineam ou Commencement de Chapitre 959 - Point 995" with translation of the Latin and French sequences to English as: Nulls 9, 99, 999; two points 909 - to the line or Beginning of the Chapter 959 - Point 995.

In several keys, we find a section with code elements that do not have any value and, in practice, function as nulls. Typically, such sections are in-



Figure 3: Section title in a cipher key (Key ID-676, 1664–1668)

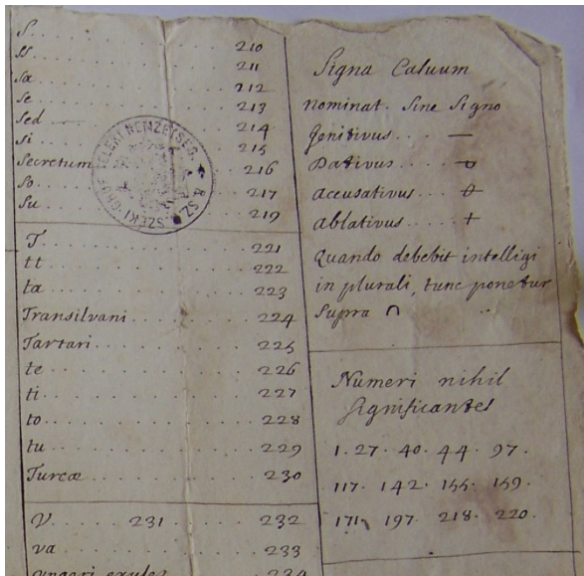


Figure 4: Explanation of code groups in a cipher key (Key ID-670, 1660–1690)

indicated with a short explanation about these missing code elements, such as "Nonvaleurs depuis 1201 jusqu'à 1250" (No value from 1201 until 1250) (Key ID-613, 1703–1711). Instructions also contain definitions of the nullities or cancellation signs by one or several intervallum such as in "Nullae a 1° usque ad 9vum, item a 450 usque ad infinitum", meaning Nulls from 1st to 9th, likewise from 450 to infinity in Figure 7, or explain how to construct or recognize them.

Not surprisingly, it is also common to find descriptions of specific parts of the cipher key table, not only providing clarity on the content of the key but also containing explicit instructions about their application and usage. An example is depicted in Figure 8 where on the top of the key document, the title describes the first table as

a key for a homophonic cipher for single letters. Below, the use of more homophones for the vowels is indicated, "Vocales quarum notæ alternatim cum superioribus adhibendæ" (The vowels, whose codes should be used alternately with the preceding ones) and on the second page, nulles are described "Errantes sed nihil significantes interdum interserent" (Nulls that signify nothing and that may be inserted sometimes).

### 5.3 Explanation of the Key

As explanatory instructions we classify texts consisting of a few sentences that are included in the cipher key table and longer texts that were written on separate slips of paper. In several instances, we find these short instructions titled as "Nota" or "NB" which abbreviates "nota bene". Hence, they were introduced to the intended user of the key by metalanguage.

Diacritics such as dots, lines or other markers placed on top or around a symbol are oftentimes used in order to change the original significance of the symbol, which can also be explained and exemplified in some of these short instructions. One instance of this is the use of dots above the code element to signify double letters. Another instance is shown in Figure 9, where placing a line on top of a code element that initially stands for the digraph "ba" reverses the order of the letters to "ab" instead. In the example given in Figure 10, the instruction indicates that a line above a code element signifies a cancellation of this sign while two or more lines mean the same as no line. The instruction is given in the second half of the right most column of a one-page cipher key shown in Figure 10, transcribed and translated as:

Linea supra vel infra numerum, seu hic litteram, seu syllabam, seu nomen denotet, ducta significat errantem. Si uero duæ, vel plures supra vel infra numerum ductæ sint lineæ, numerus significat idem, quod significat, si nulla desuper ducta sit linea.

(A line above or below a number, whether it marks a letter, or a syllable, or a name, signifies an errant one. If indeed two or more lines are drawn above or below the number, the number signifies the same as it signifies if no line were drawn above.)



Singartskini - - - 290.	Horoma - - - 420.	Nulla a 1. usq; ad 9 <sup>m</sup> Item a 450. usq; ad infinitum
Alonyom - - - 300.	Pedannum - - - 421.	
Menosikov - - - 310.	Harco - - - 422.	
Demboff - - - 320.	Instructio - - - 423.	
Sembek - - - 330.	Plenipotencia - - - 424.	
Datum	Plenipotencia	425.

Figure 7: Explanation of an interval in a cipher key (Key ID-613, 1703–1711)

Caros pro singulis Literis p[ro]hib. ut ablativum uterque

25	41	27	43	29	45	31	47
40	26	42	28	44	30	46	32
A.	b.	c.	d.	e.	f.	g.	h.
33	49	35	51	37	53	39	55
48	34	50	28	52	38	54	40
i.	k.	l.	m.	n.	o.	p.	q.
41	57	43	59	45	61	47	63
56	42	58	44	60	46	62	48
r.	s.	t.	u.	v.	x.	y.	z.

Vocales quoad notat ablativum cum superioribus adhibend.

85.	71.	87	73	89.
75.	86	72	88.	74.
A.	E.	I.	O.	U.

Figure 8: Explanation of groups of code elements in a cipher key (Key ID-700, 1664–1668)

Signum supra Syllabam  
significat inversam  
84. significat ba:  
84. significat ab. —

Figure 9: An example of diacritics explained in the instructions (Key ID-2061, 1666)

Linea supra uel infra numerum, seu hinc litteram, seu syllabam, seu nomen denotet, ducta significat errantem. Si uero dua, uel plures supra uel infra numerum ducta sint linea, numerus significat idem, quod significat, si nulla desuper ducta sit linea.

Figure 10: Explanation of diacritics in a cipher key (Key ID-1295, 1500–1699)

Longer instructions are one to several pages long, structured texts, often on separate slips of paper attached to the cipher key. They are easy to recognize, as they often are composed of numbered paragraphs, which we exemplify in Figure 12. We differentiate two classes in this category of longer instructions.

The first kind explains an unconventional cipher key that could not be otherwise intuitively applied. Some of these ciphers are particularly com-

plicated, inventions of their authors who do not suppose that the system can be appropriately used without the explanations. In such cases, sample encryptions are also included to help the learner (Láng, 2022) and (Key ID-531, 1731).

In other cases, the cipher might be a simpler but still not very widespread type, such as a matrix cipher, that requires explanations. In the case illustrated in Figure 13, the instructions continue for the rest of the page as well as the two following

Pour Chiffrer.			Pour Dechiffrer.				
a . . . 30	ba 45	pe 30	A. Sa ou Vostre Majesté,	0	y 30 . . 9	60	d
ai 5	be 60	pr 41	B. L'Empereur ou Imperial.	1	x 31	me	01
an 20	bi 95	qu . . 65	C. L'Imperatrice	2	a 32	t	02
au 01	ci . . 15	que 70	D. le Roi,	3	au 33	ca	03
b . . . 42	ie 75	r . . . 55	E. L'Electeur le	4	ck 34	sa	04
be 66	il 30	ra 20	F. Son Altesse	5	ai 35	du	05
c . . . 14	in 52	re 70	G. le Prince	6	er 36	f	06
ca 33	k 34	s . . . 97	H. Pologne	7	ss 37	pa	07
ce 71	l 22	sa 34	I. Russie	8	tz 38	a	08
ch 30	la 43	se 62	K. la France	9	m 39	en	09
ck 4	le 77	si 40	L. l'Espagne	10	b 40	pr	10
d . . . 60	li 95	ss 7	M. l'Angleterre	11	dc 41	b	11
da 47	m . . 10	st 44	N. le Prusse,	12	nc 42	la	12
de 12	ma 72	t . . . 32	O. Salatin,	13	c 43	st	13
du 35	me 31	te 70	P. la Saxe,	14	i 44	ha	14
e . . . 17	mi 16	us 55	Q. la Barriere	15	mi 45	ss	15
en 40	n . . . 24	ti 64	R. Ministre	16	e 46	da	16
er 6	na 30	ver 92	S. Alliance	17	gc 47	si	17
es 57	ne 15	un 67	T. Traité	18	fa 48	pe	18
et 31	ni 36	so 25	U. Negociation.	19	o 49	et	19
au 3	no 63	w . . . 46	V. le Cte Seinsbam	20	l 50	in	20
f . . . 36	o . . . 21	wx 27	W. le Conte de Freysing	21	p 51	r	21
fa 20	or 2	x 1	X. le Baron de Prudlohn.	22	n 52	si	22
fe 75	on 74	y . . . 0	Y. le Conte de Joerring.	23	ro 53	us	23
g . . . 30	ou 61	z . . . 96	Z. l'Armée	24	an 54	ni	24
ge 19	p . . . 23	z 9	aa. Excellence	25	we 55	es	25
h . . . 11	pa . . 37	zu 94	bb. Truppe.	26	ra 56	il	26

Figure 11: Explanation of sign separators in a cipher key (Key ID-935, 1761)

Note pour l'usage de ce Chifre

- 1<sup>o</sup> Tous les Chifres, qui dépassent le N<sup>o</sup>. 3000., servent pour des Errans, et doivent être souvent entrecoulez.
- 2<sup>o</sup> Outre cela il faut bien employer les Annulans preced. et Subseq.
- 3<sup>o</sup> les Annulans une, deux, ou plusieurs Lettres peuvent aussi servir fort utilement pour mieux cacher les articles, Surnoms, &c. en mettant au lieu des Chifres, qui signifient ca, le, de, &c. Ceux qui signifient Com, les, de, &c. et y ajoutant les annulans 1. 2. ou plusieurs Lettres, selon l'opinion de l'Esprit.
- 4<sup>o</sup> Il est encore à observer, qu'il y a dans le Chifre plusieurs doubles significations, mais qui ne causent point d'équivoque, puisque ce ne sont que des Lettres et Syllabes moins frequentes, aux quelles on a joint les Nombres et quelques Noms propres, ce qui est facile à distinguer.

Figure 12: An example with numbered paragraphs of instructions (Key ID-1722, 1790)

ones, providing insights on the usage of the key.

The second sub-category of long instructions includes a list of notes that usually accompany homophonic cipher keys and give advice on how to put them into practice. This second type does not provide us with new information about how homophonic ciphers function, rather, they show what typical mistakes the inattentive or lazy scribes made. They typically stress the importance of al-

ternating the homophones (not always using the first code element for each letter), to make full and varied use of the code elements signifying syllables, to avoid using letters or syllables for words which have a nomenclator equivalent, or they stress the importance of incorporating nulls throughout the ciphertext, as exemplified in the bottom paragraph in Figure 14.

They might furthermore instruct the user that

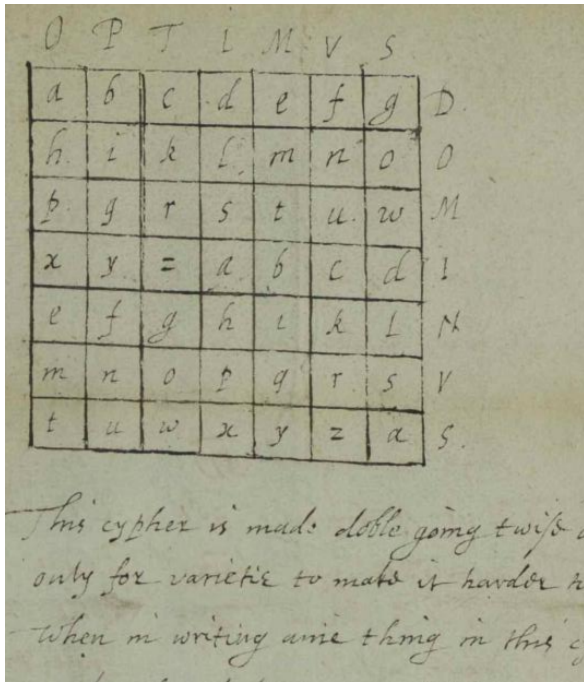


Figure 13: An example of instructions for ciphers beyond the most widespread substitution-based types (Key ID-415, 1628)

”words should not be distinguished from each other, so that in this way, the writing becomes more difficult to read.”, which means that the user should not mark word boundaries by space as we usually do in writing. Some instructions also refer to the use of punctuation. The top paragraph in Figure 14, for example, instructs the user to avoid using any apostrophes, accents or punctuation - especially if the meaning can be understood from the context.

### 5.3.1 Exemplifications

Key instructions sometimes also contain examples with plaintext and its corresponding ciphertext to clarify the application of the key, see Figure 15.

One of the keys with instructions we analyzed is a type of polyalphabetic homophonic cipher stored at the Haus-, Hof- und Staatsarchiv in Vienna, which utilizes a system of multiple encryption tables used to encrypt messages. (Key ID-1601, Year unknown) The key’s cipher is unique in that it involves a special code element, termed ”numeris indicans Tabellam”, which signals a change in the encryption or decryption table being used. Only after reading and understanding the instruction of the key and the provided exemplifications, were we able to understand how the cipher works.

These examples offer insight into how scribes

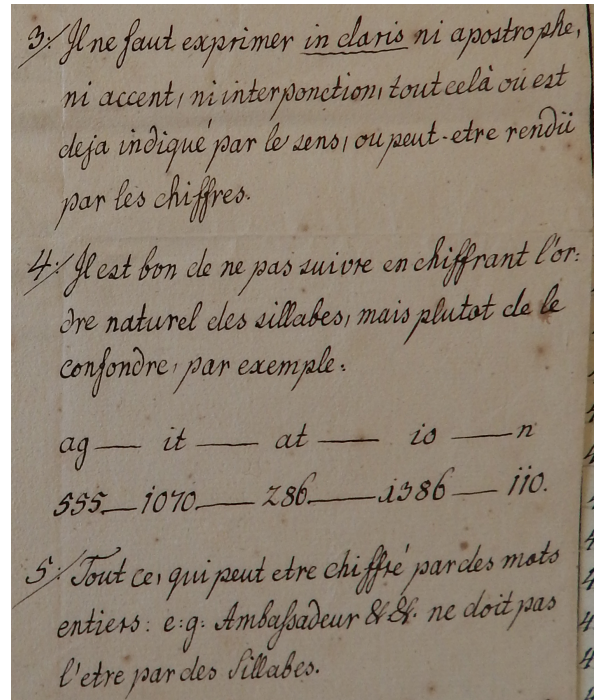


Figure 14: An itemized list of instructions (Key ID-1704, 1764)

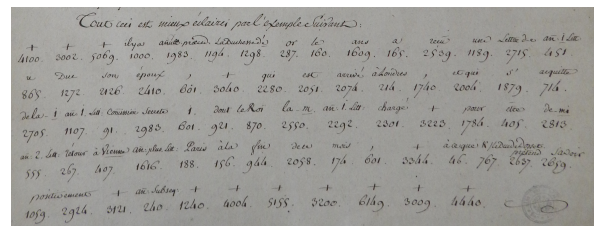


Figure 15: An example on how to use the key (Key ID-1722, 1790)

were taught to apply ciphers.

## 6 Discussion

In this study, we analyzed, to the best of our knowledge, the hitherto largest sample of cipher keys containing instructions. In order to do so, we manually labeled and described the instructions, without relying on pre-defined categories, or any existing typology. This paper presents our initial attempt to characterize the nature of instructions within cipher keys.

The scope of our study is of course constrained by the limitations of our data sample. Including more diverse sources from various locations and time periods would undoubtedly enhance the richness of our study.

Analysing the key sample, we found big overlaps in the use of language in the cipher key in-

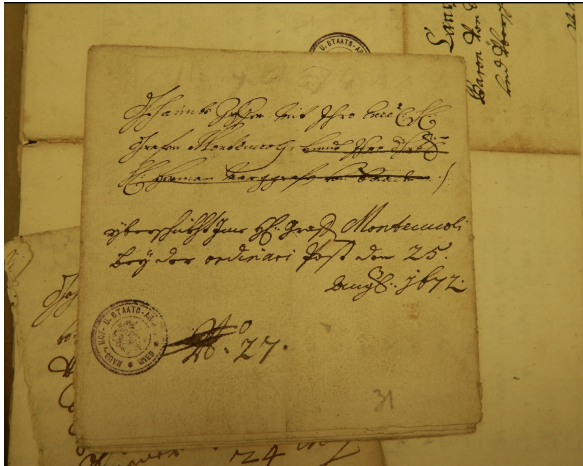


Figure 16: A note attached to a cipher key (Key ID-2044, 1672)

structions. Oftentimes, in groups of keys from the same place and time period, similar expressions and sentences were applied to describe certain operations. A case in point is the sample of cipher keys from eighteenth-century Saxony. This fact might be interpreted as a sign that instructions were copied between different cipher keys. Similarly, the consistent choice of Latin for certain types of instructions also in Early Modern times (e.g., for nullities), see (Waldispühl and Megyesi, 2024), might be explained by the transfer of knowledge between creators of cipher keys and a preference for formulaic language in the genre of instructions.

Noteworthy is the fact that keys often are accompanied by notes written on separate pieces of paper. These notes often document some kind of metadata associated with the key, such as the corresponding entities or places. Examples of a note detailing the key’s users are depicted in Figures 16 and 17. However, we do not treat these types of notes as instructions as they do not convey any information about the operational use of the keys.

## 7 Conclusion

Historians of cryptography have a wealth of knowledge about how specific ciphers were supposed to be used, and through the instructions they can gain insight into how they were actually used. Repeated advice and guidelines about what should and should not be done inform us of the fears of the cipher’s constructors, who worried about the ignorance or negligence of users. In the history of cryptography, knowledge transfer was primarily

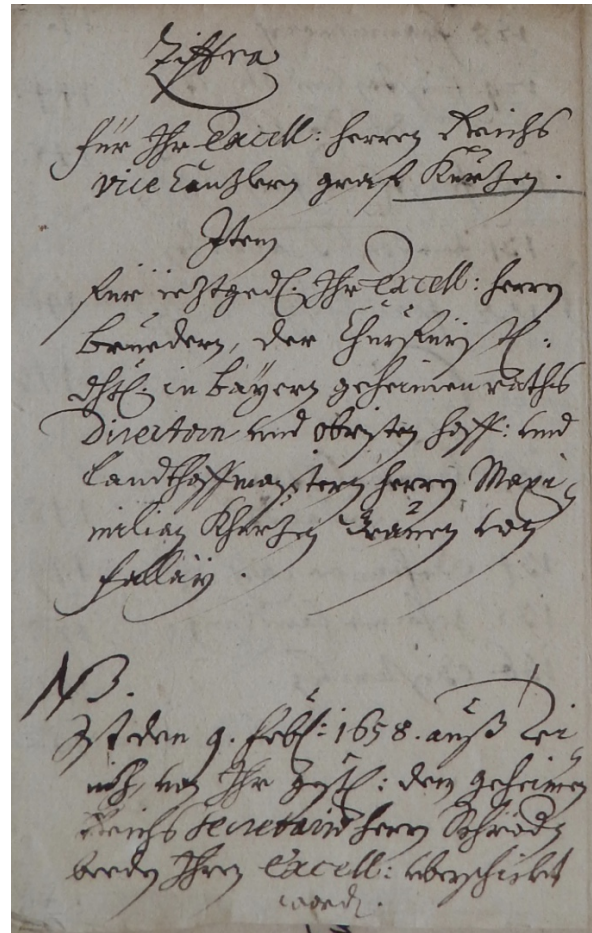


Figure 17: A note attached to a cipher key with information about the users (Key ID-1266, 1658)

oral, which we no longer have access to. Thanks to the instructions and the accompanying sample encryptions appearing in shorter or longer form, we can gain a limited but still relevant insight into how this knowledge was taught and acquired, the usual frustrations and worries of the constructors, and the mistakes of the users. To put it shortly: we get a glimpse of everyday practical cryptography.

In this work, we investigated 235 historical cipher keys that included some kind of instructions. We can conclude that ca 15% of our sample of cipher keys, all originating from early modern times in Europe, actually contained some kind of instruction with explanation about the operational application of the keys. We categorized the instructions and presented a typology based on their content. We distinguish between instructions containing structural information about the key table, information about various groups of code elements and their functions, and longer or shorter sequences of explanations about the key to help

the encrypter or decrypter to apply the key as intended by the creator of the key.

What more can we do to gain more insights into the practical usage of the cipher keys from the instructions? An obvious research direction is to widen the time period including the late 19th and early 20th centuries and/or to collect sources from a wider geographic area (including Spain, or the United States to mention a few).

A second line of attack - planned to be carried out by the present authors - is to analyse the content of the 1-2 page-long instructions more into detail. This would include text editions in the most typical languages (Latin, Italian, German, French and English), with examples in the DECODE database.

Text editions will prepare the ground for a third research direction, namely to analyse in detail, how the mostly anonymous instructions take over text elements and repeat messages from the late medieval and early modern cryptographers' advice. These would include the shorter lists of instructions by the Italian cipher designers such as Alberti, the Argentis, the Amadis, and Simonetta, as well as the thick handbooks by Della Porta, Vigenère and others.

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