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PATTERN OF BICONSONANTAL CLUSTERS IN OLD TAMIL TEXTS

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Abstract

In this paper, the frequency of biconsonantal clusters in the Sangam texts is computed using the programming language Python and its library NLTK, specifically made for natural language processing.[1] *The Sangam corpora taken for study are the oldest extant literature of Old Tamil. It consists of text corpora like the* ***Eṭṭutokai*** *('Eight Anthologies') and* ***Pattuppāṭṭu*** *('Ten Idylls'), which are collections of Old Tamil poems of Akam and Puram genres. For the present study, both the texts of* ***Eṭṭutokai*** *and* ***Pattuppāṭṭu*** *are taken.* ***Eṭṭutokai*** *is an anthology of eight poetic texts, while* ***Pattuppāṭṭu*** *is a compilation of ten texts. Our main aim in this paper is to see what the pattern in the frequencies of biconsonantal clusters is, and to explain the pattern (why is a given cluster pattern more frequent compared to the others?) emerging from Old Tamil grammatical rules. Our paper is one of the first attempts at finding a pattern of frequencies of biconsonantal clusters across all extant Old Tamil texts and then explaining it.*

[1] https://github.com/oligoglot/mayal

1. Introduction

1.1 A Note on the Transliteration

The standard followed for transliterating the names of Old Tamil texts is the ISO 15919 which is conventionally used by Tamilologists and Dravidianists. There are instances in this paper where the letters of the Tamil script are used without transliteration. A detailed list of IPA and ISO 15919 counterparts of the Tamil letters is given in the Appendix.

1.2 A Note on the Estimation of Frequencies

It is to be noted here that what we count in these Sangam texts are 'estimates' of frequencies rather than the actual frequencies. These estimates are quite close to the actual count of frequencies of biconsonantal clusters. This is so because the orthographic segmentation of words (words separated by white space) in these Sangam texts obey poetic constraints like metre, wherein each orthographic word must be of certain number of syllables only. This constraint makes it difficult to count biconsonantal clusters since a phonological word might be split orthographically at the juncture of the consonant cluster. This leads to an underestimation of the frequency count of a particular cluster. Or two phonological words can be written together without a space resulting in a 'false' biconsonantal cluster at the juncture of the two phonological words. This leads to an overestimation of the frequency count of a particular cluster. Hence, we have calculated the frequency estimates with two versions of the Old Tamil texts - one where the whole text is a continuous string of letters without any space, and the second is one where text is segmented to contain only phonological words separated by white space. Counting the biconsonantal clusters in the former version leads to an

overestimation (Type A) as it lacks white space completely. The latter version yields an underestimation (Type B) since the clusters due to morphophonemics of Old Tamil are avoided since each phonological word stands alone separated by white space. We then calculate the mean values of these two estimates. This can be quite close to the actual count. Hence, we stick to the present 'estimates' that we have outlined. The only erroneous output that we can obtain by this counting in Type A is that of prohibited clusters. These occur when two phonological words are written together without a space. But such counts of frequencies ought to be very low that we can easily spot them.

2. Cluster Frequencies

2.1 The Sangam Texts

The eight Sangam texts of **Eṭṭutokai** are **Kuṟuntokai**, **Aiṅkuṟunūṟu**, **Naṟṟiṇai**, **Kalittokai**, **Patiṟṟuppattu**, **Paripāṭal**, **Akanāṉūṟu** and **Puṟanāṉūṟu**. The texts of the **Pattuppāṭṭu** 'Ten Idylls' are **Tirumurukāṟṟuppaṭai**, **Porunarāṟṟuppaṭai**, **Ciṟupāṇāṟṟuppaṭai**, **Perumpāṇāṟṟuppaṭai**, **Mullaippāṭṭu**, **Maturaikkāñci**, **Neṭunalvāṭai**, **Kuṟiñcippāṭṭu**, **Paṭṭiṉappālai** and **Malaipaṭukaṭām**. The word Sangam refers to the **Sangam period** or **age**, which is the historical period of ancient Tamil Nadu, Kerala, and parts of Sri Lanka (then known as Tamiḻakam) spanning from c. 6th century BCE to c. 3rd century CE. It was named after the famous 'Sangam' (meaning congregation) academies of poets and scholars. The language of the Sangam works is Old Tamil (**300 BCE–700 CE**).

2.2 The Pattern of Biconsonantal Clusters

The following tables contain the frequency of occurrence of consonant clusters (con1 + con2) in the eight Sangam texts of

Eṭṭutokai and the ten Sangam texts of **Pattuppāṭṭu**. The cells with high frequency have been colour coded. A cell marked light grey would have the maximum value in that row while a cell marked medium grey would have the maximum value of frequency in that column. A cell coloured black would have the maximum value of frequency in both its row and column. The interesting pattern that emerges speaks a lot about the beauty of Tamil phonology. The light grey cells contain all the PP (geminate plosive) clusters, while the medium grey ones contain all the NNs (geminate nasal stops). The high-frequency cells marked black contain all the NPs (homorganic nasal-oral stop clusters). The Tamil script does not distinguish between voiced and voiceless consonants which occur in complementary distribution. The counting of frequencies of biconsonantal clusters is done without considering if they are inside a morpheme or across morpheme boundaries.

2.3 Maximum Likelihood Estimation

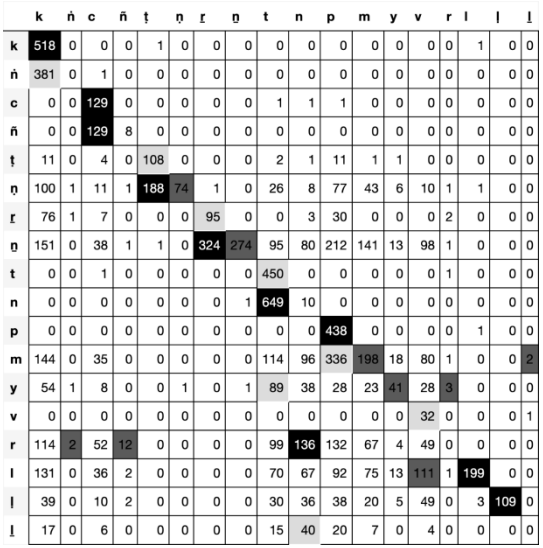
A better measure of the probability of occurrence of a consonant **c2 given** a consonant **c1**, would be the maximum likelihood estimation (MLE). For the case of biconsonantal clusters, the formula for MLE would be:

$$P(c2|c1) = count(c2, c1) / count(c1)$$

Where count(c2|c1) is the number of occurrences of c1 followed by c2, and count(c1) is the number of occurrences of c1 followed by any consonant.

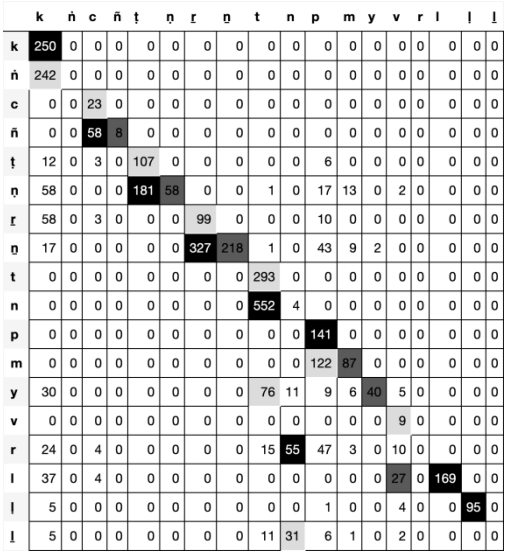
3. Visualisation of Cluster Frequencies

3.1 Aiṅkuṟunūṟu



	k	ṅ	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	518	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
ṅ	381	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	129	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
ñ	0	0	129	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	11	0	4	0	108	0	0	0	2	1	11	1	1	0	0	0	0	0
ṇ	100	1	11	1	188	74	1	0	26	8	77	43	6	10	1	1	0	0
ṟ	76	1	7	0	0	0	95	0	0	3	30	0	0	0	2	0	0	0
ṉ	151	0	38	1	1	0	324	274	95	80	212	141	13	98	1	0	0	0
t	0	0	1	0	0	0	0	0	450	0	0	0	0	0	1	0	0	0
n	0	0	0	0	0	0	0	1	649	10	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	438	0	0	0	0	1	0	0
m	144	0	35	0	0	0	0	0	114	96	336	198	18	80	1	0	0	2
y	54	1	8	0	0	1	0	1	89	38	28	23	41	28	3	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	1
r	114	2	52	12	0	0	0	0	99	136	132	67	4	49	0	0	0	0
l	131	0	36	2	0	0	0	0	70	67	92	75	13	111	1	199	0	0
ḷ	39	0	10	2	0	0	0	0	30	36	38	20	5	49	0	3	109	0
ḻ	17	0	6	0	0	0	0	0	15	40	20	7	0	4	0	0	0	0

Fig 1. Type A



	k	ṅ	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	242	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	58	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	12	0	3	0	107	0	0	0	0	0	6	0	0	0	0	0	0	0
ṇ	58	0	0	0	181	58	0	0	1	0	17	13	0	2	0	0	0	0
ṟ	58	0	3	0	0	0	99	0	0	0	10	0	0	0	0	0	0	0
ṉ	17	0	0	0	0	0	327	218	1	0	43	9	2	0	0	0	0	0
t	0	0	0	0	0	0	0	0	293	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	552	4	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	141	0	0	0	0	0	0	0
m	0	0	0	0	0	0	0	0	0	0	122	87	0	0	0	0	0	0
y	30	0	0	0	0	0	0	0	76	11	9	6	40	5	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0
r	24	0	4	0	0	0	0	0	15	55	47	3	0	10	0	0	0	0
l	37	0	4	0	0	0	0	0	0	0	0	0	0	27	0	169	0	0
ḷ	5	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	95	0
ḻ	5	0	0	0	0	0	0	0	11	31	6	1	0	2	0	0	0	0

Fig 2. Type B

	k	ṅ	c	ñ	ṭ	ṇ	r̲	n̲	t	n	p	m	y	v	r	l	l̩	l̲
k	384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	94	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	12	0	4	0	108	0	0	0	1	0	8	0	0	0	0	0	0	0
ṇ	79	0	6	0	184	66	0	0	14	4	47	28	3	6	0	0	0	0
r̲	67	0	5	0	0	0	97	0	0	2	20	0	0	0	1	0	0	0
n̲	84	0	19	0	0	0	326	246	48	40	128	75	8	49	0	0	0	0
t	0	0	0	0	0	0	0	0	372	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	600	7	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	290	0	0	0	0	0	0	0
m	72	0	18	0	0	0	0	0	57	48	229	142	9	40	0	0	0	1
y	42	0	4	0	0	0	0	0	82	24	18	14	40	16	2	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
r	69	1	28	6	0	0	0	0	57	96	90	35	2	30	0	0	0	0
l	84	0	20	1	0	0	0	0	35	34	46	38	6	69	0	184	0	0
l̩	22	0	5	1	0	0	0	0	15	18	20	10	2	26	0	2	102	0
l̲	11	0	3	0	0	0	0	0	13	36	13	4	0	3	0	0	0	0

Fig 3. Mean of Type A and Type B

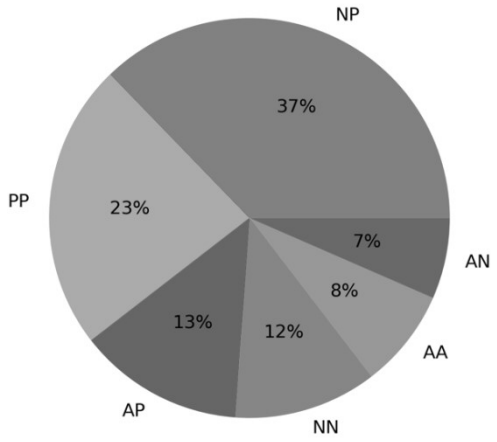
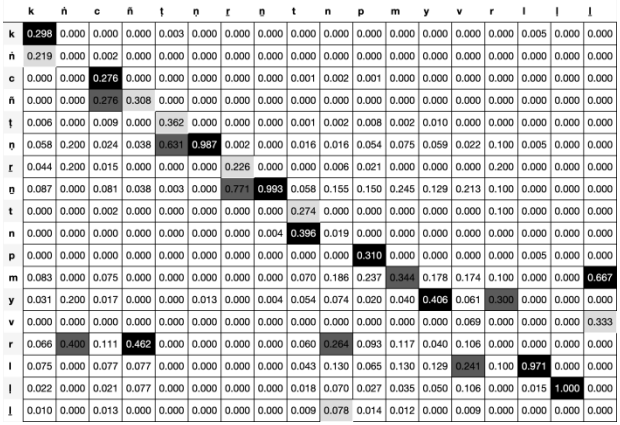
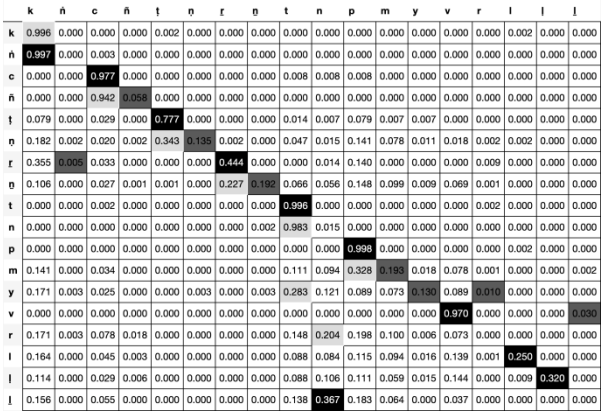


Fig 4. Pie chart of types of clusters



	k	ń	c	ñ	ʈ	ɳ	ɾ	ŋ	t	n	p	m	y	v	r	l	ɭ	ɻ
k	0.298	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000
ń	0.219	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
c	0.000	0.000	0.276	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ñ	0.000	0.000	0.276	0.308	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ʈ	0.006	0.000	0.009	0.000	0.362	0.000	0.000	0.000	0.001	0.002	0.008	0.002	0.010	0.000	0.000	0.000	0.000	0.000
ɳ	0.058	0.200	0.024	0.038	0.631	0.987	0.002	0.000	0.016	0.016	0.054	0.075	0.059	0.022	0.100	0.005	0.000	0.000
ɾ	0.044	0.200	0.015	0.000	0.000	0.000	0.226	0.000	0.000	0.006	0.021	0.000	0.000	0.000	0.200	0.000	0.000	0.000
ŋ	0.087	0.000	0.081	0.038	0.003	0.000	0.771	0.993	0.058	0.155	0.150	0.245	0.129	0.213	0.100	0.000	0.000	0.000
t	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.274	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000
n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.396	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.310	0.000	0.000	0.000	0.000	0.005	0.000	0.000
m	0.083	0.000	0.075	0.000	0.000	0.000	0.000	0.000	0.070	0.186	0.237	0.344	0.178	0.174	0.100	0.000	0.000	0.667
y	0.031	0.200	0.017	0.000	0.000	0.013	0.000	0.004	0.054	0.074	0.020	0.040	0.406	0.061	0.300	0.000	0.000	0.000
v	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.000	0.000	0.000	0.333
r	0.066	0.400	0.111	0.462	0.000	0.000	0.000	0.000	0.060	0.264	0.093	0.117	0.040	0.106	0.000	0.000	0.000	0.000
l	0.075	0.000	0.077	0.077	0.000	0.000	0.000	0.000	0.043	0.130	0.065	0.130	0.129	0.241	0.100	0.971	0.000	0.000
ɭ	0.022	0.000	0.021	0.077	0.000	0.000	0.000	0.000	0.018	0.070	0.027	0.035	0.050	0.106	0.000	0.015	1.000	0.000
ɻ	0.010	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.009	0.078	0.014	0.012	0.000	0.009	0.000	0.000	0.000	0.000

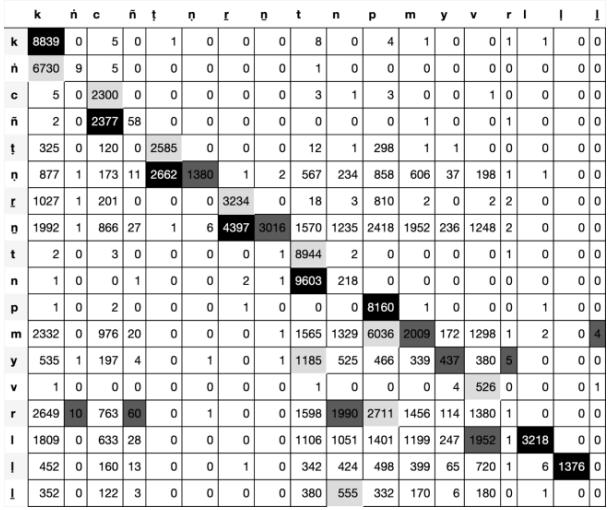
Fig 5. MLE of C2 given C1



	k	ń	c	ñ	ʈ	ɳ	ɾ	ŋ	t	n	p	m	y	v	r	l	ɭ	ɻ
k	0.996	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000
ń	0.997	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
c	0.000	0.000	0.977	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ñ	0.000	0.000	0.942	0.058	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ʈ	0.079	0.000	0.029	0.000	0.777	0.000	0.000	0.000	0.014	0.007	0.079	0.007	0.007	0.000	0.000	0.000	0.000	0.000
ɳ	0.182	0.002	0.020	0.002	0.343	0.135	0.002	0.000	0.047	0.015	0.141	0.078	0.011	0.018	0.002	0.002	0.000	0.000
ɾ	0.355	0.005	0.033	0.000	0.000	0.000	0.444	0.000	0.000	0.014	0.140	0.000	0.000	0.000	0.009	0.000	0.000	0.000
ŋ	0.106	0.000	0.027	0.001	0.001	0.000	0.227	0.192	0.066	0.056	0.148	0.099	0.009	0.069	0.001	0.000	0.000	0.000
t	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.996	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000
n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.983	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.998	0.000	0.000	0.000	0.000	0.002	0.000	0.000
m	0.141	0.000	0.034	0.000	0.000	0.000	0.000	0.000	0.111	0.094	0.328	0.193	0.018	0.078	0.001	0.000	0.000	0.002
y	0.171	0.003	0.025	0.000	0.000	0.003	0.000	0.003	0.283	0.121	0.089	0.073	0.130	0.089	0.010	0.000	0.000	0.000
v	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.970	0.000	0.000	0.000	0.030
r	0.171	0.003	0.078	0.018	0.000	0.000	0.000	0.000	0.148	0.204	0.198	0.100	0.006	0.073	0.000	0.000	0.000	0.000
l	0.164	0.000	0.045	0.003	0.000	0.000	0.000	0.000	0.088	0.084	0.115	0.094	0.016	0.139	0.001	0.250	0.000	0.000
ɭ	0.114	0.000	0.029	0.006	0.000	0.000	0.000	0.000	0.088	0.106	0.111	0.059	0.015	0.144	0.000	0.009	0.320	0.000
ɻ	0.156	0.000	0.055	0.000	0.000	0.000	0.000	0.000	0.138	0.367	0.183	0.064	0.000	0.037	0.000	0.000	0.000	0.000

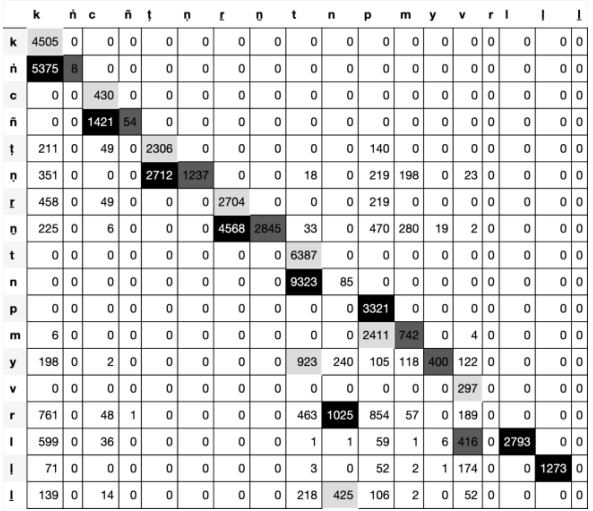
Fig 6. MLE of C1 given C2

3.2 Consolidated Eṭṭuttokai



	k	ṅ	c	ñ	ṭ	ṇ	ṛ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	8839	0	5	0	1	0	0	0	8	0	4	1	0	0	1	1	0	0
ṅ	6730	9	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
c	5	0	2300	0	0	0	0	0	3	1	3	0	0	1	0	0	0	0
ñ	2	0	2377	58	0	0	0	0	0	0	0	1	0	0	1	0	0	0
ṭ	325	0	120	0	2585	0	0	0	12	1	298	1	1	0	0	0	0	0
ṇ	877	1	173	11	2662	1380	1	2	567	234	858	606	37	198	1	1	0	0
ṛ	1027	1	201	0	0	0	3234	0	18	3	810	2	0	2	2	0	0	0
ṉ	1992	1	866	27	1	6	4397	3016	1570	1235	2418	1952	236	1248	2	0	0	0
t	2	0	3	0	0	0	0	1	8944	2	0	0	0	0	1	0	0	0
n	1	0	0	1	0	0	2	1	9603	218	0	0	0	0	0	0	0	0
p	1	0	2	0	0	0	1	0	0	0	8160	1	0	0	0	1	0	0
m	2332	0	976	20	0	0	0	1	1565	1329	6036	2009	172	1298	1	2	0	4
y	535	1	197	4	0	1	0	1	1185	525	466	339	437	380	5	0	0	0
v	1	0	0	0	0	0	0	0	1	0	0	0	4	526	0	0	0	1
r	2649	10	763	60	0	1	0	0	1598	1990	2711	1456	114	1380	1	0	0	0
l	1809	0	633	28	0	0	0	0	1106	1051	1401	1199	247	1952	1	3218	0	0
ḷ	452	0	160	13	0	0	1	0	342	424	498	399	65	720	1	6	1376	0
ḻ	352	0	122	3	0	0	0	0	380	555	332	170	6	180	0	1	0	0

Fig 7. Type A



	k	ṅ	c	ñ	ṭ	ṇ	ṛ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	4505	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	5375	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	1421	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	211	0	49	0	2306	0	0	0	0	0	140	0	0	0	0	0	0	0
ṇ	351	0	0	0	2712	1237	0	0	18	0	219	198	0	23	0	0	0	0
ṛ	458	0	49	0	0	0	2704	0	0	0	219	0	0	0	0	0	0	0
ṉ	225	0	6	0	0	0	4568	2845	33	0	470	280	19	2	0	0	0	0
t	0	0	0	0	0	0	0	0	6387	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	9323	85	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	3321	0	0	0	0	0	0	0
m	6	0	0	0	0	0	0	0	0	0	2411	742	0	4	0	0	0	0
y	198	0	2	0	0	0	0	0	923	240	105	118	400	122	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	297	0	0	0	0
r	761	0	48	1	0	0	0	0	463	1025	854	57	0	189	0	0	0	0
l	599	0	36	0	0	0	0	0	1	1	59	1	6	416	0	2793	0	0
ḷ	71	0	0	0	0	0	0	0	3	0	52	2	1	174	0	0	1273	0
ḻ	139	0	14	0	0	0	0	0	218	425	106	2	0	52	0	0	0	0

Fig 8. Type B

	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	l̩	l̲
k	6672	0	2	0	0	0	0	0	4	0	2	0	0	0	0	0	0	0
ṅ	6052	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	2	0	1365	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0
ñ	1	0	1899	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	268	0	84	0	2446	0	0	0	6	0	219	0	0	0	0	0	0	0
ṇ	614	0	86	6	2687	1308	0	1	292	117	538	402	18	110	0	0	0	0
r̲	742	0	125	0	0	0	2969	0	9	2	514	1	0	1	1	0	0	0
ṉ	1108	0	436	14	0	3	4482	2930	802	618	1444	1116	128	625	1	0	0	0
t	1	0	2	0	0	0	0	0	7666	1	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	1	0	9463	152	0	0	0	0	0	0	0	0
p	0	0	1	0	0	0	0	0	0	0	5740	0	0	0	0	0	0	0
m	1169	0	488	10	0	0	0	0	782	664	4224	1376	86	651	0	1	0	2
y	366	0	100	2	0	0	0	0	1054	382	286	228	418	251	2	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	2	412	0	0	0	0
r	1705	5	406	30	0	0	0	0	1030	1508	1782	756	57	784	0	0	0	0
l	1204	0	334	14	0	0	0	0	554	526	730	600	126	1184	0	3006	0	0
l̩	262	0	80	6	0	0	0	0	172	212	275	200	33	447	0	3	1324	0
l̲	246	0	68	2	0	0	0	0	299	490	219	86	3	116	0	0	0	0

Fig 9. Mean of Type A and Type B

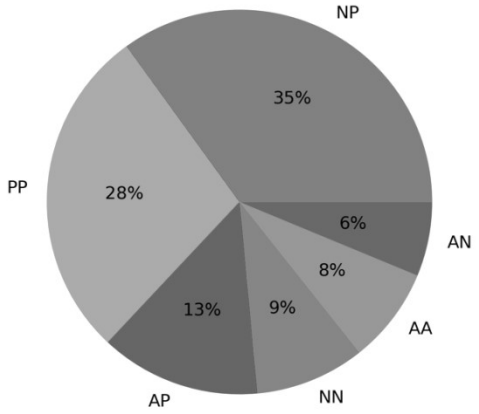


Fig 10. Pie chart of types of clusters

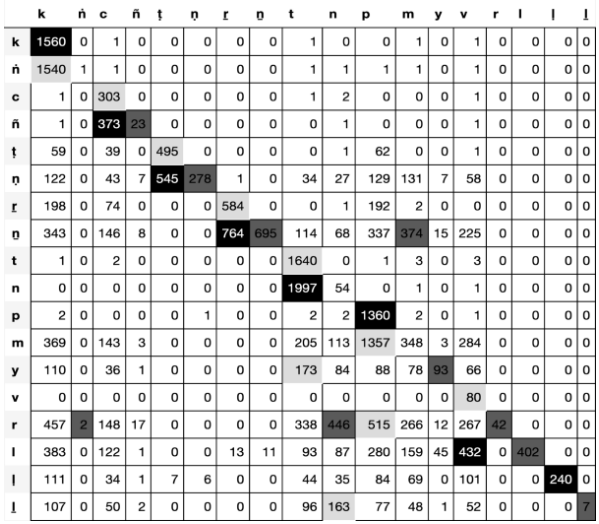
	k	ń	c	ñ	ʈ	ɳ	ɾ	ŋ	t	n	p	m	y	v	r	l	ɭ	ɻ
k	0.316	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000
ń	0.241	0.391	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
c	0.000	0.000	0.258	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ñ	0.000	0.000	0.267	0.258	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000
ʈ	0.012	0.000	0.013	0.000	0.492	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.001	0.000	0.000	0.000	0.000	0.000
ɳ	0.031	0.043	0.019	0.049	0.507	0.994	0.000	0.001	0.021	0.031	0.036	0.074	0.028	0.025	0.059	0.000	0.000	0.000
ɾ	0.037	0.043	0.023	0.000	0.000	0.000	0.424	0.000	0.001	0.000	0.034	0.000	0.000	0.000	0.118	0.000	0.000	0.000
ŋ	0.071	0.043	0.097	0.120	0.000	0.004	0.576	0.998	0.058	0.163	0.101	0.240	0.179	0.158	0.118	0.000	0.000	0.000
t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.332	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000
n	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.357	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.340	0.000	0.000	0.000	0.000	0.000	0.000	0.000
m	0.083	0.000	0.110	0.089	0.000	0.000	0.000	0.000	0.058	0.176	0.252	0.247	0.130	0.165	0.059	0.001	0.000	0.800
y	0.019	0.043	0.022	0.018	0.000	0.001	0.000	0.000	0.044	0.069	0.019	0.042	0.331	0.048	0.294	0.000	0.000	0.000
v	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.067	0.000	0.000	0.000	0.200
r	0.095	0.435	0.086	0.267	0.000	0.001	0.000	0.000	0.059	0.263	0.113	0.179	0.086	0.175	0.059	0.000	0.000	0.000
l	0.065	0.000	0.071	0.124	0.000	0.000	0.000	0.000	0.041	0.139	0.058	0.147	0.187	0.248	0.059	0.996	0.000	0.000
ɭ	0.016	0.000	0.018	0.058	0.000	0.000	0.000	0.000	0.013	0.056	0.021	0.049	0.049	0.091	0.059	0.002	1.000	0.000
ɻ	0.013	0.000	0.014	0.013	0.000	0.000	0.000	0.000	0.014	0.073	0.014	0.021	0.005	0.023	0.000	0.000	0.000	0.000

Fig 11. MLE of C2 given C1

	k	ń	c	ñ	ʈ	ɳ	ɾ	ŋ	t	n	p	m	y	v	r	l	ɭ	ɻ
k	0.998	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ń	0.998	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
c	0.002	0.000	0.994	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ñ	0.001	0.000	0.975	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ʈ	0.097	0.000	0.036	0.000	0.773	0.000	0.000	0.000	0.004	0.000	0.089	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ɳ	0.115	0.000	0.023	0.001	0.350	0.181	0.000	0.000	0.075	0.031	0.113	0.080	0.005	0.026	0.000	0.000	0.000	0.000
ɾ	0.194	0.000	0.038	0.000	0.000	0.000	0.610	0.000	0.003	0.001	0.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ŋ	0.105	0.000	0.046	0.001	0.000	0.000	0.232	0.159	0.083	0.065	0.127	0.103	0.012	0.066	0.000	0.000	0.000	0.000
t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.977	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
m	0.148	0.000	0.062	0.001	0.000	0.000	0.000	0.099	0.084	0.383	0.128	0.011	0.082	0.000	0.000	0.000	0.000	0.000
y	0.131	0.000	0.048	0.001	0.000	0.000	0.000	0.291	0.129	0.114	0.083	0.107	0.093	0.001	0.000	0.000	0.000	0.000
v	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.008	0.987	0.000	0.000	0.000	0.000	0.002
r	0.208	0.001	0.060	0.005	0.000	0.000	0.000	0.126	0.156	0.213	0.114	0.009	0.108	0.000	0.000	0.000	0.000	0.000
l	0.143	0.000	0.050	0.002	0.000	0.000	0.000	0.087	0.083	0.111	0.095	0.020	0.154	0.000	0.254	0.000	0.000	0.000
ɭ	0.101	0.000	0.036	0.003	0.000	0.000	0.000	0.077	0.095	0.112	0.090	0.015	0.162	0.000	0.001	0.309	0.000	0.000
ɻ	0.168	0.000	0.058	0.001	0.000	0.000	0.000	0.181	0.264	0.158	0.081	0.003	0.086	0.000	0.000	0.000	0.000	0.000

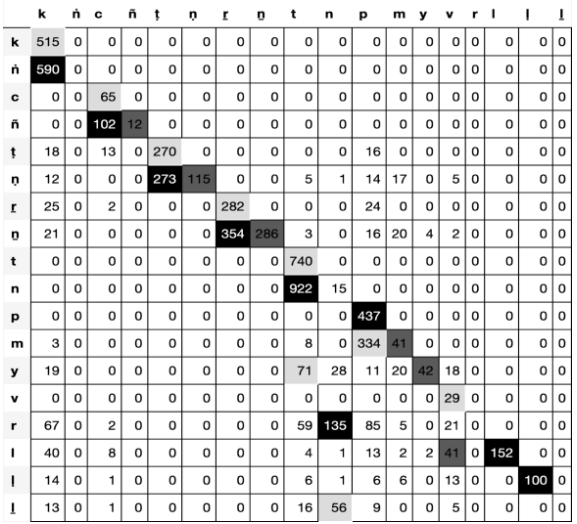
Fig 12. MLE of C1 given C2

3.3 Consolidated Pattuppāṭṭu



	k	ṅ	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	1560	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0
ṅ	1540	1	1	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0
c	1	0	303	0	0	0	0	0	1	2	0	0	0	1	0	0	0	0
ñ	1	0	373	23	0	0	0	0	0	1	0	0	0	1	0	0	0	0
ṭ	59	0	39	0	495	0	0	0	0	1	62	0	0	1	0	0	0	0
ṇ	122	0	43	7	545	278	1	0	34	27	129	131	7	58	0	0	0	0
ṟ	198	0	74	0	0	0	584	0	0	1	192	2	0	0	0	0	0	0
ṉ	343	0	146	8	0	0	764	695	114	68	337	374	15	225	0	0	0	0
t	1	0	2	0	0	0	0	0	1640	0	1	3	0	3	0	0	0	0
n	0	0	0	0	0	0	0	0	1997	54	0	1	0	1	0	0	0	0
p	2	0	0	0	0	1	0	0	2	2	1360	2	0	1	0	0	0	0
m	369	0	143	3	0	0	0	0	205	113	1357	348	3	284	0	0	0	0
y	110	0	36	1	0	0	0	0	173	84	88	78	93	66	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0
r	457	2	148	17	0	0	0	0	338	446	515	266	12	267	42	0	0	0
l	383	0	122	1	0	0	13	11	93	87	280	159	45	432	0	402	0	0
ḷ	111	0	34	1	7	6	0	0	44	35	84	69	0	101	0	0	240	0
ḻ	107	0	50	2	0	0	0	0	96	163	77	48	1	52	0	0	0	7

Fig 13. Type A



	k	ṅ	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	590	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	102	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	18	0	13	0	270	0	0	0	0	0	16	0	0	0	0	0	0	0
ṇ	12	0	0	0	273	115	0	0	5	1	14	17	0	5	0	0	0	0
ṟ	25	0	2	0	0	0	282	0	0	0	24	0	0	0	0	0	0	0
ṉ	21	0	0	0	0	0	354	286	3	0	16	20	4	2	0	0	0	0
t	0	0	0	0	0	0	0	0	740	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	922	15	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	437	0	0	0	0	0	0	0
m	3	0	0	0	0	0	0	0	8	0	334	41	0	0	0	0	0	0
y	19	0	0	0	0	0	0	0	71	28	11	20	42	18	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0
r	67	0	2	0	0	0	0	0	59	135	85	5	0	21	0	0	0	0
l	40	0	8	0	0	0	0	0	4	1	13	2	2	41	0	152	0	0
ḷ	14	0	1	0	0	0	0	0	6	1	6	6	0	13	0	0	100	0
ḻ	13	0	1	0	0	0	0	0	16	56	9	0	0	5	0	0	0	0

Fig 14. Type B

	k	ṅ	c	ñ	ṭ	ṇ	r̲	n̲	t	n	p	m	y	v	r	l	l̤	l̲
k	1038	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	1065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	184	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
ñ	0	0	238	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	38	0	26	0	382	0	0	0	0	0	39	0	0	0	0	0	0	0
ṇ	67	0	22	4	409	196	0	0	20	14	72	74	4	32	0	0	0	0
r̲	112	0	38	0	0	0	433	0	0	0	108	1	0	0	0	0	0	0
n̲	182	0	73	4	0	0	559	490	58	34	176	197	10	114	0	0	0	0
t	0	0	1	0	0	0	0	0	1190	0	0	2	0	2	0	0	0	0
n	0	0	0	0	0	0	0	0	1460	34	0	0	0	0	0	0	0	0
p	1	0	0	0	0	0	0	0	1	1	898	1	0	0	0	0	0	0
m	186	0	72	2	0	0	0	0	106	56	846	194	2	142	0	0	0	0
y	64	0	18	0	0	0	0	0	122	56	50	49	68	42	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	54	0	0	0	0
r	262	1	75	8	0	0	0	0	198	290	300	136	6	144	21	0	0	0
l	212	0	65	0	0	0	6	6	48	44	146	80	24	236	0	277	0	0
l̤	62	0	18	0	4	3	0	0	25	18	45	38	0	57	0	0	170	0
l̲	60	0	26	1	0	0	0	0	56	110	43	24	0	28	0	0	0	4

Fig 15. Mean of Type A and Type B

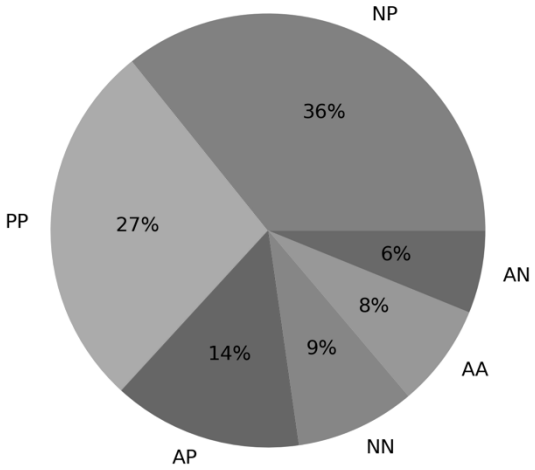
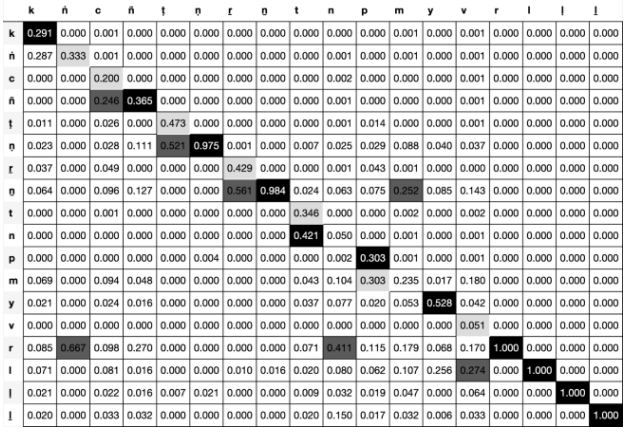
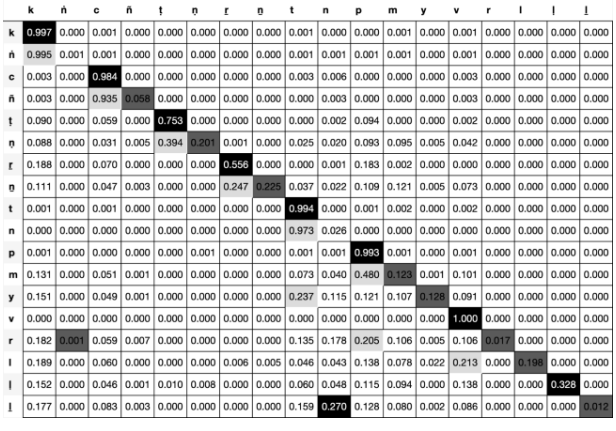


Fig 16. Pie chart of types of clusters



	k	ń	c	ñ	ʈ	ɳ	ɾ	ŋ	t	n	p	m	y	v	r	l	ɭ	ɻ
k	0.291	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
ń	0.287	0.333	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
c	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
ñ	0.000	0.000	0.246	0.365	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
ʈ	0.011	0.000	0.026	0.000	0.473	0.000	0.000	0.000	0.000	0.001	0.014	0.000	0.000	0.001	0.000	0.000	0.000	0.000
ɳ	0.023	0.000	0.028	0.111	0.521	0.975	0.001	0.000	0.007	0.025	0.029	0.088	0.040	0.037	0.000	0.000	0.000	0.000
ɾ	0.037	0.000	0.049	0.000	0.000	0.000	0.429	0.000	0.000	0.001	0.043	0.001	0.000	0.000	0.000	0.000	0.000	0.000
ŋ	0.064	0.000	0.096	0.127	0.000	0.000	0.561	0.984	0.024	0.063	0.075	0.252	0.085	0.143	0.000	0.000	0.000	0.000
t	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.346	0.000	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.000
n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.421	0.050	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
p	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.002	0.303	0.001	0.000	0.001	0.000	0.000	0.000	0.000
m	0.069	0.000	0.094	0.048	0.000	0.000	0.000	0.000	0.043	0.104	0.303	0.235	0.017	0.180	0.000	0.000	0.000	0.000
y	0.021	0.000	0.024	0.016	0.000	0.000	0.000	0.000	0.037	0.077	0.020	0.053	0.528	0.042	0.000	0.000	0.000	0.000
v	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.000	0.000	0.000	0.000
r	0.085	0.667	0.098	0.270	0.000	0.000	0.000	0.000	0.071	0.411	0.115	0.179	0.068	0.170	1.000	0.000	0.000	0.000
l	0.071	0.000	0.081	0.016	0.000	0.000	0.010	0.016	0.020	0.080	0.062	0.107	0.256	0.274	0.000	1.000	0.000	0.000
ɭ	0.021	0.000	0.022	0.016	0.007	0.021	0.000	0.000	0.009	0.032	0.019	0.047	0.000	0.064	0.000	0.000	1.000	0.000
ɻ	0.020	0.000	0.033	0.032	0.000	0.000	0.000	0.000	0.020	0.150	0.017	0.032	0.006	0.033	0.000	0.000	0.000	1.000

Fig 17. MLE of C2 given C1

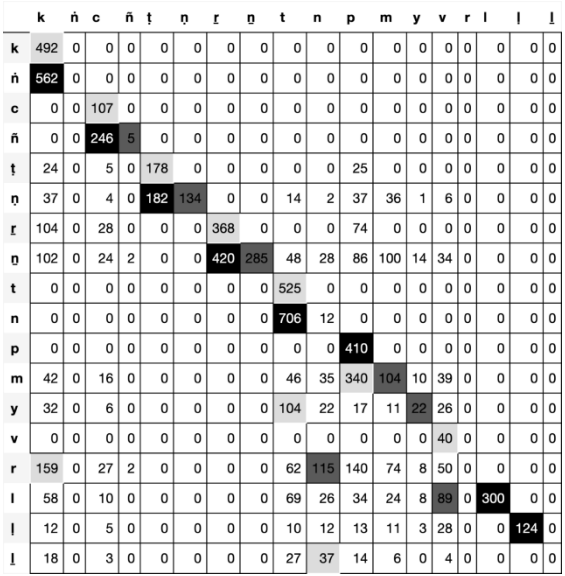


	k	ń	c	ñ	ʈ	ɳ	ɾ	ŋ	t	n	p	m	y	v	r	l	ɭ	ɻ
k	0.997	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
ń	0.995	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
c	0.003	0.000	0.984	0.000	0.000	0.000	0.000	0.000	0.003	0.006	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
ñ	0.003	0.000	0.935	0.058	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
ʈ	0.090	0.000	0.059	0.000	0.753	0.000	0.000	0.000	0.000	0.002	0.094	0.000	0.000	0.002	0.000	0.000	0.000	0.000
ɳ	0.088	0.000	0.031	0.005	0.394	0.201	0.001	0.000	0.025	0.020	0.093	0.095	0.005	0.042	0.000	0.000	0.000	0.000
ɾ	0.188	0.000	0.070	0.000	0.000	0.000	0.556	0.000	0.000	0.001	0.183	0.002	0.000	0.000	0.000	0.000	0.000	0.000
ŋ	0.111	0.000	0.047	0.003	0.000	0.000	0.247	0.225	0.037	0.022	0.109	0.121	0.005	0.073	0.000	0.000	0.000	0.000
t	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.994	0.000	0.001	0.002	0.000	0.002	0.000	0.000	0.000	0.000
n	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.973	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.993	0.001	0.000	0.001	0.000	0.000	0.000	0.000
m	0.131	0.000	0.051	0.001	0.000	0.000	0.000	0.000	0.073	0.040	0.480	0.128	0.001	0.101	0.000	0.000	0.000	0.000
y	0.151	0.000	0.049	0.001	0.000	0.000	0.000	0.000	0.237	0.115	0.121	0.107	0.128	0.091	0.000	0.000	0.000	0.000
v	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
r	0.182	0.001	0.059	0.007	0.000	0.000	0.000	0.000	0.135	0.178	0.205	0.106	0.005	0.106	0.017	0.000	0.000	0.000
l	0.189	0.000	0.060	0.000	0.000	0.000	0.006	0.005	0.046	0.043	0.138	0.078	0.022	0.213	0.000	0.198	0.000	0.000
ɭ	0.152	0.000	0.046	0.001	0.010	0.008	0.000	0.000	0.060	0.048	0.115	0.094	0.000	0.138	0.000	0.000	0.328	0.000
ɻ	0.177	0.000	0.083	0.003	0.000	0.000	0.000	0.000	0.159	0.270	0.128	0.080	0.002	0.086	0.000	0.000	0.000	0.012

Fig 18. MLE of C1 given C2

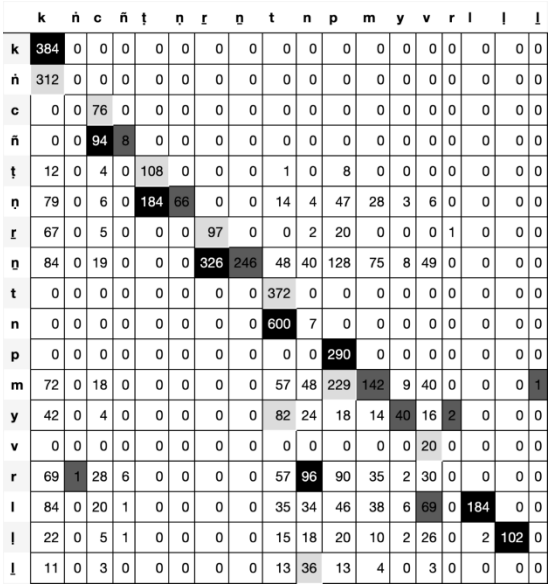
4. Mean Values of all Texts

4.1 Eṭṭutokai



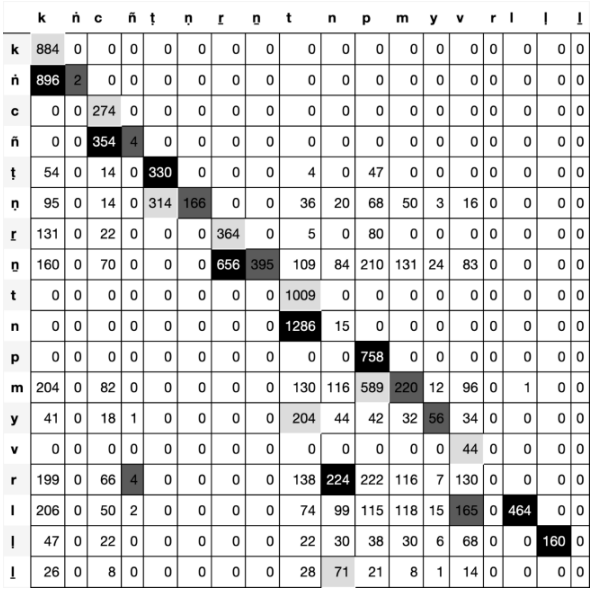
	k	ṅ	c	ñ	ṭ	ṇ	r̲	n̲	t	n	p	m	y	v	r	l	ḷ	l̲
k	492	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	562	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	246	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	24	0	5	0	178	0	0	0	0	0	25	0	0	0	0	0	0	0
ṇ	37	0	4	0	182	134	0	0	14	2	37	36	1	6	0	0	0	0
r̲	104	0	28	0	0	0	368	0	0	0	74	0	0	0	0	0	0	0
n̲	102	0	24	2	0	0	420	285	48	28	86	100	14	34	0	0	0	0
t	0	0	0	0	0	0	0	0	525	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	706	12	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	410	0	0	0	0	0	0	0
m	42	0	16	0	0	0	0	0	46	35	340	104	10	39	0	0	0	0
y	32	0	6	0	0	0	0	0	104	22	17	11	22	26	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0
r	159	0	27	2	0	0	0	0	62	115	140	74	8	50	0	0	0	0
l	58	0	10	0	0	0	0	0	69	26	34	24	8	89	0	300	0	0
ḷ	12	0	5	0	0	0	0	0	10	12	13	11	3	28	0	0	124	0
l̲	18	0	3	0	0	0	0	0	27	37	14	6	0	4	0	0	0	0

Fig 19. **Kuṟuntokai**



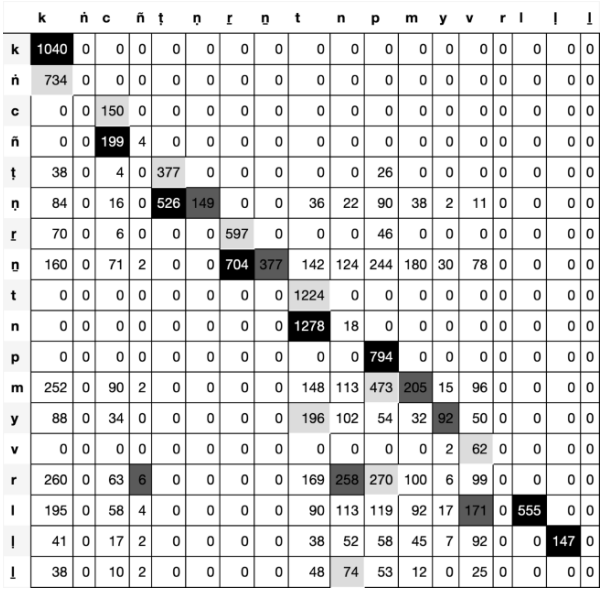
	k	ṅ	c	ñ	ṭ	ṇ	r̲	n̲	t	n	p	m	y	v	r	l	ḷ	l̲
k	384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	94	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	12	0	4	0	108	0	0	0	1	0	8	0	0	0	0	0	0	0
ṇ	79	0	6	0	184	66	0	0	14	4	47	28	3	6	0	0	0	0
r̲	67	0	5	0	0	0	97	0	0	2	20	0	0	0	1	0	0	0
n̲	84	0	19	0	0	0	326	246	48	40	128	75	8	49	0	0	0	0
t	0	0	0	0	0	0	0	0	372	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	600	7	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	290	0	0	0	0	0	0	0
m	72	0	18	0	0	0	0	0	57	48	229	142	9	40	0	0	0	1
y	42	0	4	0	0	0	0	0	82	24	18	14	40	16	2	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
r	69	1	28	6	0	0	0	0	57	96	90	35	2	30	0	0	0	0
l	84	0	20	1	0	0	0	0	35	34	46	38	6	69	0	184	0	0
ḷ	22	0	5	1	0	0	0	0	15	18	20	10	2	26	0	2	102	0
l̲	11	0	3	0	0	0	0	0	13	36	13	4	0	3	0	0	0	0

Fig 20. **Aiṅkuṟunūṟu**



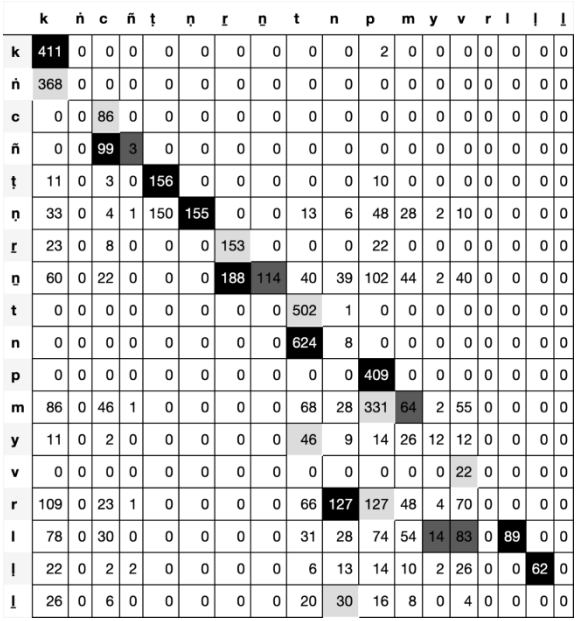
	k	ń	c	ñ	ṭ	ṇ	r̲	ŋ̲	t	n	p	m	y	v	r	l	l̩	l̲
k	884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ń	896	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	274	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	354	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	54	0	14	0	330	0	0	0	4	0	47	0	0	0	0	0	0	0
ṇ	95	0	14	0	314	166	0	0	36	20	68	50	3	16	0	0	0	0
r̲	131	0	22	0	0	0	364	0	5	0	80	0	0	0	0	0	0	0
ŋ̲	160	0	70	0	0	0	656	395	109	84	210	131	24	83	0	0	0	0
t	0	0	0	0	0	0	0	0	1009	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	1286	15	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	758	0	0	0	0	0	0	0
m	204	0	82	0	0	0	0	0	130	116	589	220	12	96	0	1	0	0
y	41	0	18	1	0	0	0	0	204	44	42	32	56	34	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	44	0	0	0	0
r	199	0	66	4	0	0	0	0	138	224	222	116	7	130	0	0	0	0
l	206	0	50	2	0	0	0	0	74	99	115	118	15	165	0	464	0	0
l̩	47	0	22	0	0	0	0	0	22	30	38	30	6	68	0	0	160	0
l̲	26	0	8	0	0	0	0	0	28	71	21	8	1	14	0	0	0	0

Fig 21. **Narr̲iṇai**



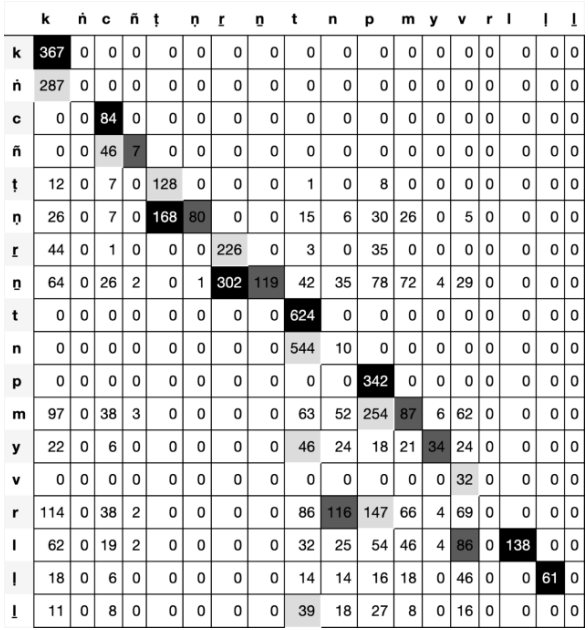
	k	ń	c	ñ	ṭ	ṇ	r̲	ŋ̲	t	n	p	m	y	v	r	l	l̩	l̲
k	1040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ń	734	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	199	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	38	0	4	0	377	0	0	0	0	0	26	0	0	0	0	0	0	0
ṇ	84	0	16	0	526	149	0	0	36	22	90	38	2	11	0	0	0	0
r̲	70	0	6	0	0	0	597	0	0	0	46	0	0	0	0	0	0	0
ŋ̲	160	0	71	2	0	0	704	377	142	124	244	180	30	78	0	0	0	0
t	0	0	0	0	0	0	0	0	1224	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	1278	18	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	794	0	0	0	0	0	0	0
m	252	0	90	2	0	0	0	0	148	113	473	205	15	96	0	0	0	0
y	88	0	34	0	0	0	0	0	196	102	54	32	92	50	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	2	62	0	0	0	0
r	260	0	63	6	0	0	0	0	169	258	270	100	6	99	0	0	0	0
l	195	0	58	4	0	0	0	0	90	113	119	92	17	171	0	555	0	0
l̩	41	0	17	2	0	0	0	0	38	52	58	45	7	92	0	0	147	0
l̲	38	0	10	2	0	0	0	0	48	74	53	12	0	25	0	0	0	0

Fig 22. **Kalittokai**



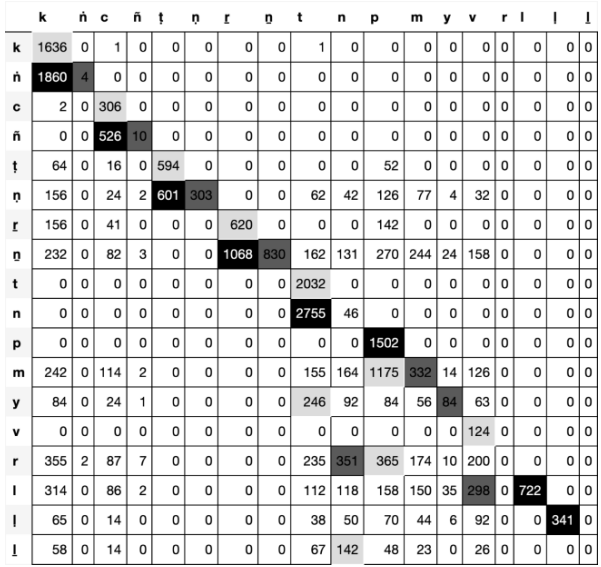
	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	l̲
k	411	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
ṅ	368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	99	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	11	0	3	0	156	0	0	0	0	0	10	0	0	0	0	0	0	0
ṇ	33	0	4	1	150	155	0	0	13	6	48	28	2	10	0	0	0	0
r̲	23	0	8	0	0	0	153	0	0	0	22	0	0	0	0	0	0	0
ṉ	60	0	22	0	0	0	188	114	40	39	102	44	2	40	0	0	0	0
t	0	0	0	0	0	0	0	0	502	1	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	624	8	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	409	0	0	0	0	0	0	0
m	86	0	46	1	0	0	0	0	68	28	331	64	2	55	0	0	0	0
y	11	0	2	0	0	0	0	0	46	9	14	26	12	12	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0
r	109	0	23	1	0	0	0	0	66	127	127	48	4	70	0	0	0	0
l	78	0	30	0	0	0	0	0	31	28	74	54	14	83	0	89	0	0
ḷ	22	0	2	2	0	0	0	0	6	13	14	10	2	26	0	0	62	0
l̲	26	0	6	0	0	0	0	0	20	30	16	8	0	4	0	0	0	0

Fig 23. **Patir̲r̲uppattu**



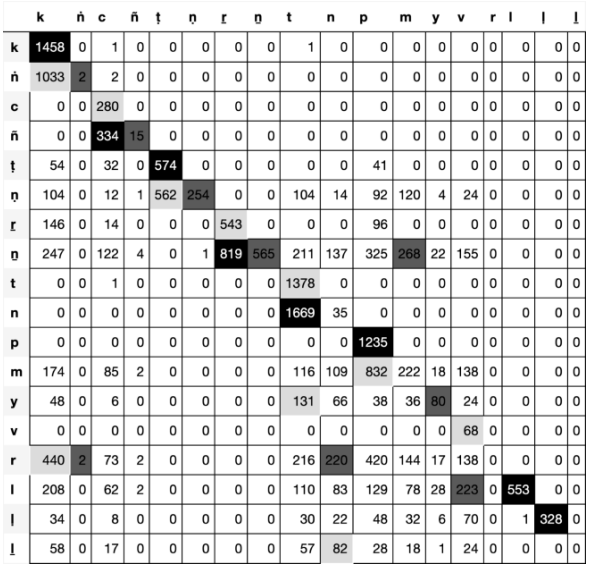
	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	l̲
k	367	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	287	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	46	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	12	0	7	0	128	0	0	0	1	0	8	0	0	0	0	0	0	0
ṇ	26	0	7	0	168	80	0	0	15	6	30	26	0	5	0	0	0	0
r̲	44	0	1	0	0	0	226	0	3	0	35	0	0	0	0	0	0	0
ṉ	64	0	26	2	0	1	302	119	42	35	78	72	4	29	0	0	0	0
t	0	0	0	0	0	0	0	0	624	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	544	10	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	342	0	0	0	0	0	0	0
m	97	0	38	3	0	0	0	0	63	52	254	87	6	62	0	0	0	0
y	22	0	6	0	0	0	0	0	46	24	18	21	34	24	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0
r	114	0	38	2	0	0	0	0	86	116	147	66	4	69	0	0	0	0
l	62	0	19	2	0	0	0	0	32	25	54	46	4	86	0	138	0	0
ḷ	18	0	6	0	0	0	0	0	14	14	16	18	0	46	0	0	61	0
l̲	11	0	8	0	0	0	0	0	39	18	27	8	0	16	0	0	0	0

Fig 24. **Paripāṭal**



	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	l̲
k	1636	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ṅ	1860	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	2	0	306	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	526	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	64	0	16	0	594	0	0	0	0	0	52	0	0	0	0	0	0	0
ṇ	156	0	24	2	601	303	0	0	62	42	126	77	4	32	0	0	0	0
r̲	156	0	41	0	0	0	620	0	0	0	142	0	0	0	0	0	0	0
ṉ	232	0	82	3	0	0	1068	830	162	131	270	244	24	158	0	0	0	0
t	0	0	0	0	0	0	0	0	2032	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	2755	46	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	1502	0	0	0	0	0	0	0
m	242	0	114	2	0	0	0	0	155	164	1175	332	14	126	0	0	0	0
y	84	0	24	1	0	0	0	0	246	92	84	56	84	63	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	124	0	0	0	0
r	355	2	87	7	0	0	0	0	235	351	365	174	10	200	0	0	0	0
l	314	0	86	2	0	0	0	0	112	118	158	150	35	298	0	722	0	0
ḷ	65	0	14	0	0	0	0	0	38	50	70	44	6	92	0	0	341	0
l̲	58	0	14	0	0	0	0	0	67	142	48	23	0	26	0	0	0	0

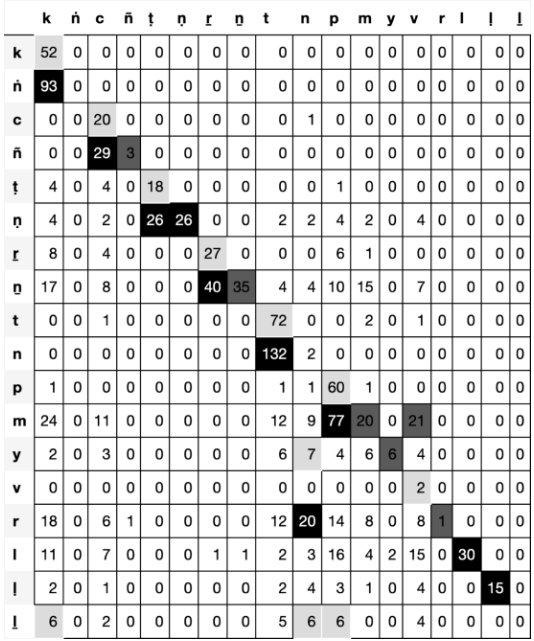
Fig 25. **Akanāṉūṟu**



	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	l̲
k	1458	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ṅ	1033	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	334	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	54	0	32	0	574	0	0	0	0	0	41	0	0	0	0	0	0	0
ṇ	104	0	12	1	562	254	0	0	104	14	92	120	4	24	0	0	0	0
r̲	146	0	14	0	0	0	543	0	0	0	96	0	0	0	0	0	0	0
ṉ	247	0	122	4	0	1	819	565	211	137	325	268	22	155	0	0	0	0
t	0	0	1	0	0	0	0	0	1378	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	1669	35	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	1235	0	0	0	0	0	0	0
m	174	0	85	2	0	0	0	0	116	109	832	222	18	138	0	0	0	0
y	48	0	6	0	0	0	0	0	131	66	38	36	80	24	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	68	0	0	0	0
r	440	2	73	2	0	0	0	0	216	220	420	144	17	138	0	0	0	0
l	208	0	62	2	0	0	0	0	110	83	129	78	28	223	0	553	0	0
ḷ	34	0	8	0	0	0	0	0	30	22	48	32	6	70	0	1	328	0
l̲	58	0	17	0	0	0	0	0	57	82	28	18	1	24	0	0	0	0

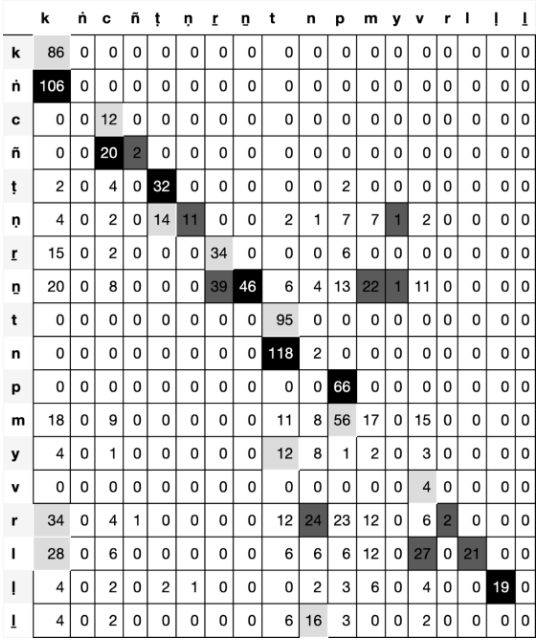
Fig 26. **Puṟanāṉūṟu**

4.2 Pattuppāṭṭu



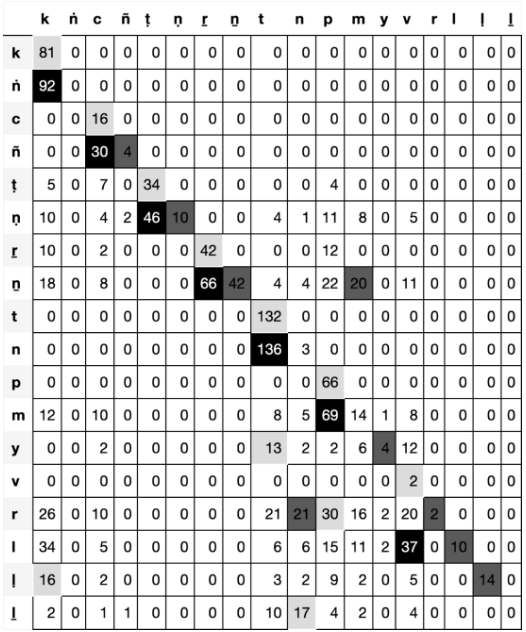
	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	l̲
k	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
ñ	0	0	29	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	4	0	4	0	18	0	0	0	0	0	1	0	0	0	0	0	0	0
ṇ	4	0	2	0	26	26	0	0	2	2	4	2	0	4	0	0	0	0
r̲	8	0	4	0	0	0	27	0	0	0	6	1	0	0	0	0	0	0
ṉ	17	0	8	0	0	0	40	35	4	4	10	15	0	7	0	0	0	0
t	0	0	1	0	0	0	0	0	72	0	0	2	0	1	0	0	0	0
n	0	0	0	0	0	0	0	0	132	2	0	0	0	0	0	0	0	0
p	1	0	0	0	0	0	0	0	1	1	60	1	0	0	0	0	0	0
m	24	0	11	0	0	0	0	0	12	9	77	20	0	21	0	0	0	0
y	2	0	3	0	0	0	0	0	6	7	4	6	6	4	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
r	18	0	6	1	0	0	0	0	12	20	14	8	0	8	1	0	0	0
l	11	0	7	0	0	0	1	1	2	3	16	4	2	15	0	30	0	0
ḷ	2	0	1	0	0	0	0	0	2	4	3	1	0	4	0	0	15	0
l̲	6	0	2	0	0	0	0	0	5	6	6	0	0	4	0	0	0	0

Fig 27. **Kuṟiñcippāṭṭu**



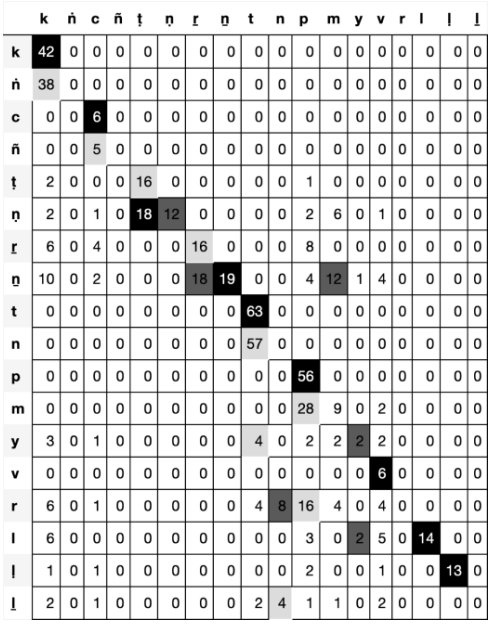
	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	l̲
k	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	20	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	2	0	4	0	32	0	0	0	0	0	2	0	0	0	0	0	0	0
ṇ	4	0	2	0	14	11	0	0	2	1	7	7	1	2	0	0	0	0
r̲	15	0	2	0	0	0	34	0	0	0	6	0	0	0	0	0	0	0
ṉ	20	0	8	0	0	0	39	46	6	4	13	22	1	11	0	0	0	0
t	0	0	0	0	0	0	0	0	95	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	118	2	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	66	0	0	0	0	0	0	0
m	18	0	9	0	0	0	0	0	11	8	56	17	0	15	0	0	0	0
y	4	0	1	0	0	0	0	0	12	8	1	2	0	3	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
r	34	0	4	1	0	0	0	0	12	24	23	12	0	6	2	0	0	0
l	28	0	6	0	0	0	0	0	6	6	6	12	0	27	0	21	0	0
ḷ	4	0	2	0	2	1	0	0	0	2	3	6	0	4	0	0	19	0
l̲	4	0	2	0	0	0	0	0	6	16	3	0	0	2	0	0	0	0

Fig 28. **Ciṟupāṇāṟṟuppaṭai**



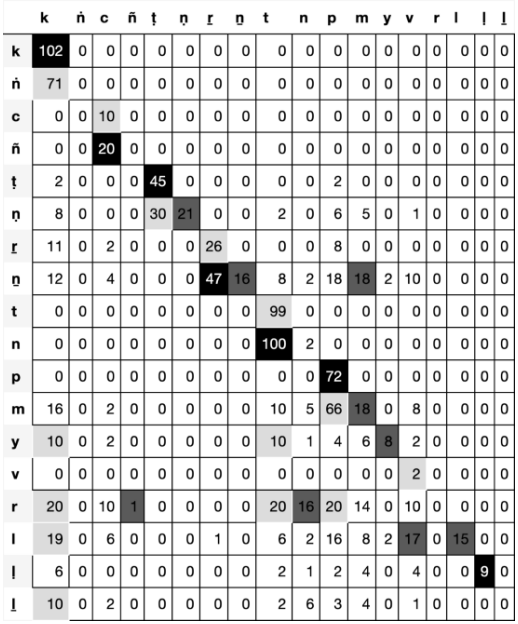
	k	ń	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ń	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	30	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	5	0	7	0	34	0	0	0	0	0	4	0	0	0	0	0	0	0
ṇ	10	0	4	2	46	10	0	0	4	1	11	8	0	5	0	0	0	0
ṟ	10	0	2	0	0	0	42	0	0	0	12	0	0	0	0	0	0	0
ṉ	18	0	8	0	0	0	66	42	4	4	22	20	0	11	0	0	0	0
t	0	0	0	0	0	0	0	0	132	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	136	3	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	66	0	0	0	0	0	0	0
m	12	0	10	0	0	0	0	0	8	5	69	14	1	8	0	0	0	0
y	0	0	2	0	0	0	0	0	13	2	2	6	4	12	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
r	26	0	10	0	0	0	0	0	21	21	30	16	2	20	2	0	0	0
l	34	0	5	0	0	0	0	0	6	6	15	11	2	37	0	10	0	0
ḷ	16	0	2	0	0	0	0	0	3	2	9	2	0	5	0	0	14	0
ḻ	2	0	1	1	0	0	0	0	10	17	4	2	0	4	0	0	0	0

Fig 29. **Tirumurukāṟṟuppaṭai**



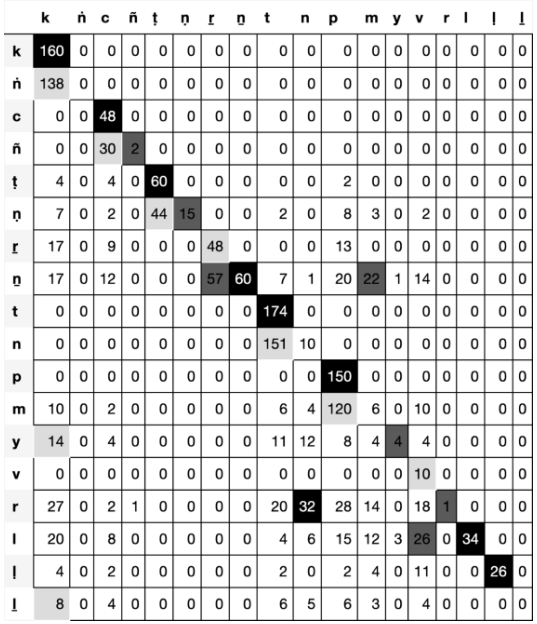
	k	ń	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ń	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	2	0	0	0	16	0	0	0	0	0	1	0	0	0	0	0	0	0
ṇ	2	0	1	0	18	12	0	0	0	0	2	6	0	1	0	0	0	0
ṟ	6	0	4	0	0	0	16	0	0	0	8	0	0	0	0	0	0	0
ṉ	10	0	2	0	0	0	18	19	0	0	4	12	1	4	0	0	0	0
t	0	0	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	57	0	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	56	0	0	0	0	0	0	0
m	0	0	0	0	0	0	0	0	0	0	28	9	0	2	0	0	0	0
y	3	0	1	0	0	0	0	0	4	0	2	2	2	2	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
r	6	0	1	0	0	0	0	0	4	8	16	4	0	4	0	0	0	0
l	6	0	0	0	0	0	0	0	0	0	3	0	2	5	0	14	0	0
ḷ	1	0	1	0	0	0	0	0	0	0	2	0	0	1	0	0	13	0
ḻ	2	0	1	0	0	0	0	0	2	4	1	1	0	2	0	0	0	0

Fig 30. **Neṭunalvāṭai**



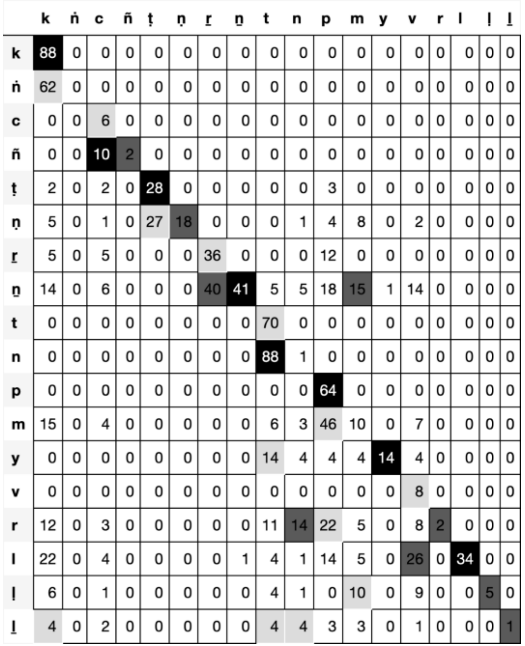
	k	ṅ	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	2	0	0	0	45	0	0	0	0	0	2	0	0	0	0	0	0	0
ṇ	8	0	0	0	30	21	0	0	2	0	6	5	0	1	0	0	0	0
ṟ	11	0	2	0	0	0	26	0	0	0	8	0	0	0	0	0	0	0
ṉ	12	0	4	0	0	0	47	16	8	2	18	18	2	10	0	0	0	0
t	0	0	0	0	0	0	0	0	99	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	100	2	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	72	0	0	0	0	0	0	0
m	16	0	2	0	0	0	0	0	10	5	66	18	0	8	0	0	0	0
y	10	0	2	0	0	0	0	0	10	1	4	6	8	2	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
r	20	0	10	1	0	0	0	0	20	16	20	14	0	10	0	0	0	0
l	19	0	6	0	0	0	1	0	6	2	16	8	2	17	0	15	0	0
ḷ	6	0	0	0	0	0	0	0	2	1	2	4	0	4	0	0	9	0
ḻ	10	0	2	0	0	0	0	0	2	6	3	4	0	1	0	0	0	0

Fig 31. **Paṭṭiṉappālai**



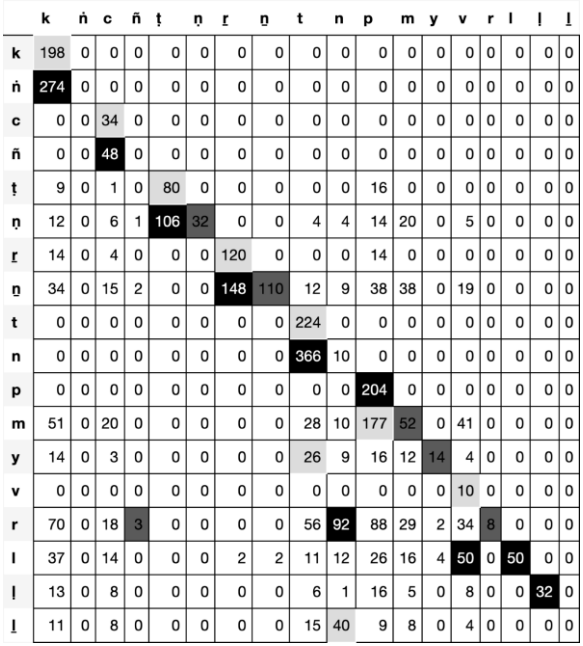
	k	ṅ	c	ñ	ṭ	ṇ	ṟ	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	30	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	4	0	4	0	60	0	0	0	0	0	2	0	0	0	0	0	0	0
ṇ	7	0	2	0	44	15	0	0	2	0	8	3	0	2	0	0	0	0
ṟ	17	0	9	0	0	0	48	0	0	0	13	0	0	0	0	0	0	0
ṉ	17	0	12	0	0	0	57	60	7	1	20	22	1	14	0	0	0	0
t	0	0	0	0	0	0	0	0	174	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	151	10	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	150	0	0	0	0	0	0	0
m	10	0	2	0	0	0	0	0	6	4	120	6	0	10	0	0	0	0
y	14	0	4	0	0	0	0	0	11	12	8	4	4	4	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
r	27	0	2	1	0	0	0	0	20	32	28	14	0	18	1	0	0	0
l	20	0	8	0	0	0	0	0	4	6	15	12	3	26	0	34	0	0
ḷ	4	0	2	0	0	0	0	0	2	0	2	4	0	11	0	0	26	0
ḻ	8	0	4	0	0	0	0	0	6	5	6	3	0	4	0	0	0	0

Fig 32. **Perumpāṇāṟṟuppaṭai**



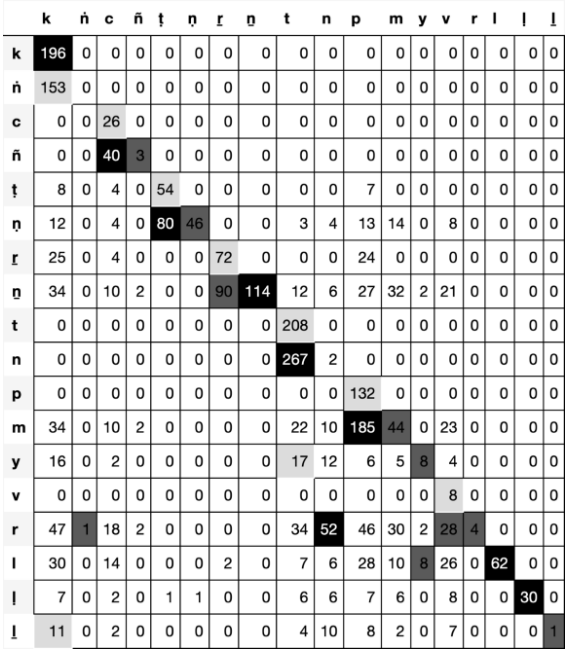
	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	2	0	2	0	28	0	0	0	0	0	3	0	0	0	0	0	0	0
ṇ	5	0	1	0	27	18	0	0	0	1	4	8	0	2	0	0	0	0
r̲	5	0	5	0	0	0	36	0	0	0	12	0	0	0	0	0	0	0
ṉ	14	0	6	0	0	0	40	41	5	5	18	15	1	14	0	0	0	0
t	0	0	0	0	0	0	0	0	70	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	88	1	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0	0
m	15	0	4	0	0	0	0	0	6	3	46	10	0	7	0	0	0	0
y	0	0	0	0	0	0	0	0	14	4	4	4	14	4	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
r	12	0	3	0	0	0	0	0	11	14	22	5	0	8	2	0	0	0
l	22	0	4	0	0	0	0	1	4	1	14	5	0	26	0	34	0	0
ḷ	6	0	1	0	0	0	0	0	4	1	0	10	0	9	0	0	5	0
ḻ	4	0	2	0	0	0	0	0	4	4	3	3	0	1	0	0	0	1

Fig 33. **Porunarā̲r̲uppaṭai**



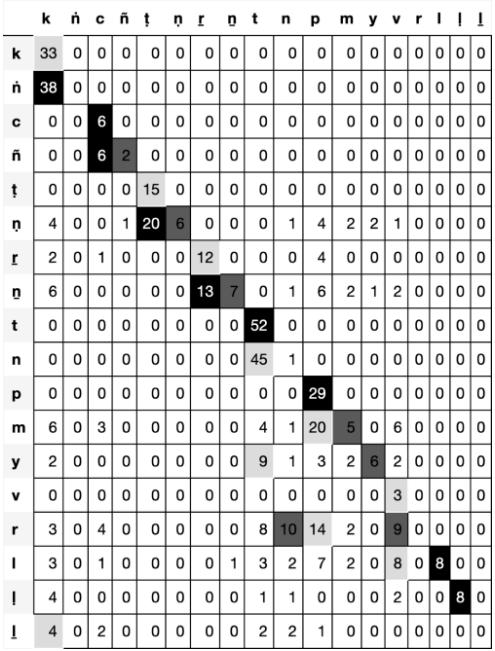
	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	274	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	9	0	1	0	80	0	0	0	0	0	16	0	0	0	0	0	0	0
ṇ	12	0	6	1	106	32	0	0	4	4	14	20	0	5	0	0	0	0
r̲	14	0	4	0	0	0	120	0	0	0	14	0	0	0	0	0	0	0
ṉ	34	0	15	2	0	0	148	110	12	9	38	38	0	19	0	0	0	0
t	0	0	0	0	0	0	0	0	224	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	366	10	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	204	0	0	0	0	0	0	0
m	51	0	20	0	0	0	0	0	28	10	177	52	0	41	0	0	0	0
y	14	0	3	0	0	0	0	0	26	9	16	12	14	4	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
r	70	0	18	3	0	0	0	0	56	92	88	29	2	34	8	0	0	0
l	37	0	14	0	0	0	2	2	11	12	26	16	4	50	0	50	0	0
ḷ	13	0	8	0	0	0	0	0	6	1	16	5	0	8	0	0	32	0
ḻ	11	0	8	0	0	0	0	0	15	40	9	8	0	4	0	0	0	0

Fig 34. **Maturaikkāñci**



	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	153	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	40	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	8	0	4	0	54	0	0	0	0	0	7	0	0	0	0	0	0	0
ṇ	12	0	4	0	80	46	0	0	3	4	13	14	0	8	0	0	0	0
r̲	25	0	4	0	0	0	72	0	0	0	24	0	0	0	0	0	0	0
ṉ	34	0	10	2	0	0	90	114	12	6	27	32	2	21	0	0	0	0
t	0	0	0	0	0	0	0	0	208	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	267	2	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	132	0	0	0	0	0	0	0
m	34	0	10	2	0	0	0	0	22	10	185	44	0	23	0	0	0	0
y	16	0	2	0	0	0	0	0	17	12	6	5	8	4	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
r	47	1	18	2	0	0	0	0	34	52	46	30	2	28	4	0	0	0
l	30	0	14	0	0	0	2	0	7	6	28	10	8	26	0	62	0	0
ḷ	7	0	2	0	1	1	0	0	6	6	7	6	0	8	0	0	30	0
ḻ	11	0	2	0	0	0	0	0	4	10	8	2	0	7	0	0	0	1

Fig 35. **Malaipaṭukaṭām**



	k	ṅ	c	ñ	ṭ	ṇ	r̲	ṉ	t	n	p	m	y	v	r	l	ḷ	ḻ
k	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṅ	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ñ	0	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ṭ	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
ṇ	4	0	0	1	20	6	0	0	0	1	4	2	2	1	0	0	0	0
r̲	2	0	1	0	0	0	12	0	0	0	4	0	0	0	0	0	0	0
ṉ	6	0	0	0	0	0	13	7	0	1	6	2	1	2	0	0	0	0
t	0	0	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0	0
n	0	0	0	0	0	0	0	0	45	1	0	0	0	0	0	0	0	0
p	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0
m	6	0	3	0	0	0	0	0	4	1	20	5	0	6	0	0	0	0
y	2	0	0	0	0	0	0	0	9	1	3	2	6	2	0	0	0	0
v	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
r	3	0	4	0	0	0	0	0	8	10	14	2	0	9	0	0	0	0
l	3	0	1	0	0	0	0	1	3	2	7	2	0	8	0	8	0	0
ḷ	4	0	0	0	0	0	0	0	1	1	0	0	0	2	0	0	8	0
ḻ	4	0	2	0	0	0	0	0	2	2	1	0	0	0	0	0	0	0

Fig 36. **Mullaippāṭṭu**

The software that we developed using NLTK, Matplotlib and Pandas libraries of Python in order to perform these computations is available for viewing and testing at https://github.com/ oligoglot/mayal. The input texts used for the computation are available at https://github.com/ oligoglot/ mayal/tree/main/corpora. The complete set of tables for all the 18 works can be downloaded from https://github.com/oligoglot/ mayal/tree/main/out.

5. Types of Biconsonantal Clusters

The above tables illustrate the phonotactic pattern of biconsonantal clusters in the Old Tamil texts. Let us abstract these phonotactic patterns into formulae - the highly frequent biconsonantal clusters are **NP** (Nasal plus Plosive cluster), followed by **PP** (a geminate Plosive). The **NN** clusters (a geminate Nasal stop) are not as frequent as the NPs and PPs. They are akin in their frequency to **AP** (Approximant plus Plosive) and **AA** (geminate Approximant or Hetero-organic Approximant cluster) clusters. There is also the **AN** (Approximant plus Nasal) cluster whose only realisation is the cluster **rn ற்ற**. We can produce a general ranking among these types of biconsonantal clusters:

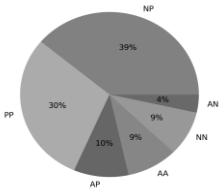


Fig 37. **Pie chart of clusters in the overall corpus**

NP > PP > AP > AA > NN > AN

6. Interpretation

6.1 Interpretation of High Frequency Values

The following tables contain the consonant clusters that have high frequency of occurrence in each of the texts of **Eṭṭutokai** and **Pattuppāṭṭu**:

Colour code	Most frequent clusters	Consonant clusters in **Eṭṭutokai** and **Pattuppāṭṭu**
	Contains most PPs	kk, cc, ṭṭ, r̲r̲, tt, mp, yt, vv, rp, l̲n
	Contains most NPs	ṅk, ñc, ṇṭ, n̲r̲, nt, pp, ll, l̤l̤
	Contains most NNs	ññ, ṇṇ, n̲n̲, mm, yy, yr, ml̲, rṅ, rn, lv

Table 1 - **Colour code and biconsonantal clusters**

Why does such a clear and neat pattern emerge? Let us look at it in probabilistic terms. Take a row of an oral stop, say **க் k**. What is the most frequent consonant that occurs after **க் k**? In other words, given that con1 is **க் k**, what con2 has the highest probability of occurring after it? Of course, it is **க் k** which is most probable to occur after **க் k**, representing a geminate stop cluster. This high probability is what is reflected in the high-frequency value. Hence the cell coloured light grey in each row are mostly geminate oral stops.

What about the nasal stops? Why aren't the maximum values in rows nasal geminates? Take a row of a nasal stop, say **ண் ṇ**. What is the con2 that is highly probable to occur after a nasal stop **ண் ṇ**? It is not **ண் ṇ** itself but the oral stop **ட் ṭ**. This is so because, in Tamil phonology, it is highly probable for a homorganic oral

stop to occur after a nasal stop than any other consonant. This is reflected in the frequency values - the highest of all frequencies are the Nasal+Oral stop clusters. Hence the black cells that have the highest frequencies (maximum in both their respective rows and columns) contain all NP clusters.

However, if you look column-wise, the maximum value in each will be that of nasal geminates. This is so because looking column-wise, we are looking at the probability of a con1 occurring before a nasal stop con2. Given a nasal stop con2, it is highly probable that it is preceded by the same nasal stop. Hence, all medium grey cells contain all the NNs. Some NN clusters are significantly absent, namely - ங்ங **ṅṅ** and ஞ்ஞ **nn**. Given an oral stop con2, it is highly probable that it is preceded by a homorganic nasal stop.

These frequency tabulations and the following maximum likelihood estimates are significant aspects of the phonological grammar of Old Tamil.[2]

6.2 Scribal Errors

The exceptionally low frequency values are likely a result of scribal errors being handed down without any correction in the Canonical Old Tamil texts. Some of these phonotactically prohibited clusters that do appear are deemed to be the result of scribal errors. Some of these clusters are **kṭ, kr, kl, ṅt, ct, cn** etc. When rounding off the MLE values (fig. 11, 12, 17, 18) of these error frequencies they turn out to be zero.

[2] The frequency pattern is consistent with what traditional grammars of Tamil have outlined. See *Tolkkāppiyam* 48, 49.

6.3 Morphophonemic Reasons for High Frequency Clusters

1. Among verbs with an affective-effective[3] contrast, the NP vs PP is morphologically productive. Transitive/Effective verbs have the PP cluster while the Intransitive/Affective verbs have the NP cluster. This can contribute to a high number of PPs and NPs in the text. e.g., tr. அடக்கு aṭa**kk**u 'suppress' vs intr. அடங்கு aṭa**ṅk**u 'get suppressed.'
2. Among compound nouns, there is geminate PP (தங்கம் taṅkam 'gold' + கிண்ணம் kiṇṇam 'bowl' > தங்கக்கிண்ணம் taṅka**kk**iṇṇam 'golden bowl') due to sandhi or an NP (மா mā 'mango' + பழம் pa̲lam 'ripe fruit' > மாம்பழம் māmpa̲lam 'mango fruit') formed at the word/morpheme boundaries. This can lead to a high number of PPs and NPs.
3. Gemination of oral stops is a morphologically productive mechanism in the formation of a genitive out of a noun (ஆடு āṭu 'goat' > ஆட்டு āṭ**ṭ**u 'of the goat'). This increases the number of PPs.
4. Besides, many nouns and verbs have PP, NP and NN clusters as part of their roots. e.g., பக்கம் pa**kk**am 'side,' தங்கு ta**ṅk**u 'stay,' அம்மா a**mm**ā 'mother.'
5. A morpho-phonemic rule states that a lateral or nasal in the coda of a monosyllabic morpheme of the form (C)VC (where V is a short vowel) geminates on concatenation of a vowel-intial suffix. E.g., கல் kal 'stone' + உ u epenthetic vowel > கல்லு ka**ll**u, கண் kaṇ 'eye' + இல் il locative case > ka**ṇṇ**il

[3] The oldest extant Grammatical treatise on Tamil, the **Tolkkāppiyam** calls these as **ta̲nvi̲nai** ('action acting on self') and **pi̲ravi̲nai** ('action acting on other').

'in the eye.' This gemination rule contributes to the number of AA and NN clusters.

6. There is a morpho-phonemic phenomenon mentioned in the குற்றியலுகரப் புணரியல் Kurriyalukarap puṇariyal chapter of the Tolkāppiyam (Rangan K. 2012): the terminal NP cluster of the first noun, upon assimilation becomes a PP cluster, on concatenation of the second noun in the formation of compound nouns.

   E.g., kura**ṅk**u 'monkey' + kāl 'leg' > kura**kk**uk kāl 'monkey's leg'

   Such productive applications of morphological/ morphophonological rules result in high frequencies of certain clusters.

6.4 Possible Reasons for High Frequency of NP Clusters

The pioneering linguist Robert Caldwell, who wrote the first comparative grammar of Dravidian languages, mentions a phenomenon in Tamil called the **Euphonic Nunnation** or Nasalisation. He defines one specific case of euphonic nunnation in Tamil as: "the insertion of a nasal before the initial consonant of the formative suffix of many nouns and verbs." (Caldwell 1875). By 'formative suffix' he means the non-morphemic, vestigial suffixes appended to bare roots of nouns and verbs in Tamil (and other Dravidian languages) which had meaning in Proto-Dravidian but has lost it in the daughter languages.

An example would be the formation of demonstrative adjectives **anda** 'that,' **inda** 'this' from demonstrative pronouns **adu** 'that,' **idu** 'this.' Suffixation of the adjectival participial **'a'** after the addition of the euphonic nasal before the stop derives the demonstrative adjectives.

ad(u) ‘that’ (dem. pronoun) + **a** (adj. participial) > **and + a** > **anda** ‘that’ (dem. adjective)

This process of euphonic nunnation could be one reason for the high number of NP clusters. This phenomenon seems to be less prevalent in Modern Kannada and Telugu. Hence comparative studies give us cognates for Tamil nouns and verbs in Kannada or Telugu with a single stop counterpart to Tamil’s nasal+stop cluster.

e.g., Kannada eraḍu ‘two’
Tamil iraṇḍu ‘two’
Kannada mūru ‘three’
Tamil mūṉṟu ‘three’

Caldwell says that “the formatives ‘**ndu**’ and ‘**mbu**’ are extremely common terminations of Tamil nouns". Here again he specifies that euphonic nunnation, as a process, further differentiated Tamil from its sister languages. Cf. Tamil eṟu-**mb**u ‘ant’ and Kannada iru-**v**e ‘id.’ Malayalam, a sister Dravidian language much closer to Tamil than Kannada, has carried this euphonic nunnation further to a geminate nasal, as in the following example:

Malayalam mūṉṉu ‘three’

Kumaraswami Raja [1969] has proposed that NP and PP clusters in Tamil could be reflexes of the Proto-Dravidian *NP and *NPP clusters, respectively.

6.5 Generalisation of Pattern of Biconsonantal Clusters

The high-frequency clusters point out the permissible biconsonantal clusters and also their productivity in word formation. The Old Tamil biconsonantal clusters can be abstracted and we can arrive at the general formulae of biconsonantal clusters:

NP, PP, NN, AA, AP, AN

Where P is the set of Oral stops/Plosives = {**k, c, ṭ, t, p, r̲**} = {க், ச், ட், த், ப், ற்}

N is the set of Nasal stops = {**ṅ, ñ, ṇ, n, m, n̲**} = {ங், ஞ், ண், ந், ம், ன்}

A is the set of Approximants = {Retroflex approximant, Laterals, Rhotics, Glides}

= {(**l̲**), (**l, ḷ**), (**r**), (**v, y**)}

= {(ழ்), (ல், ள்), (ர்), (வ், ய்)}

Obstruents in Old Tamil include only the oral stops, as it lacked affricates and fricatives. However Modern Tamil has affricates and fricatives. The letter **c ச்** represented the palatal stop in Old Tamil. However, it is realised as a fricative or an affricate in Modern Tamil.

The Phonotactics of Old Tamil can be realised by the formulae NP, PP, NN, AP, AA, and AN. Unlike English which has PL clusters (Plosive + Liquid), Old Tamil has LP and LPP clusters. Old Tamil also does not have PN, PA clusters since it disallows consonant clusters in Onset position of a syllable.

Triconsonantal clusters are never tautosyllabic and are broken down into a biconsonantal cluster which forms the coda of a preceding syllable and the remaining consonant forms the onset of the following syllable. Onsets never have clusters in Old Tamil.

7. Conclusion

We have programmatically computed the frequencies as well as the Maximum Likelihood Estimation of all possible consonant clusters across the complete corpora of extant Old Tamil texts. From the tabulated results, we have identified a general pattern among the permissible and frequent consonant clusters. We have

also listed the morphological contrasts and morpho-phonological rules behind the pattern. It is our position that these factors significantly contribute to the high frequency of NP, PP, NN and AA clusters rather than happenstance patterns of NP, PP, NN, AA clusters in lexical items like ampu ‘arrow’, appa ‘father’, amma ‘mother’, ayya ‘master’ respectively.

8. Appendix

List of IPA and ISO 15919 equivalents to the letters of the Tamil script

Tamil Script - Vowels	ISO 15919	IPA
அ	a	ə, ʌ
ஆ	ā	aː
இ	i	ɪ
ஈ	ī	iː
உ	u	u, ɯ
ஊ	ū	uː
எ	e	ɛ
ஏ	ē	eː
ஐ	ai	aɪ
ஒ	o	o
ஓ	ō	oː
ஔ	au	aʊ

Tamil Script - Consonants	ISO 15919	IPA
க்	k	k
ங்	ṅ	ŋ
ச்	c	c
ஞ்	ñ	ɲ
ட்	ṭ	ʈ
ண்	ṇ	ɳ
ற்	r̲	t
ன்	n̲	n
த்	t	t̪
ந்	n	n̪
ப்	p	p
ம்	m	m
ய்	y	j
ர்	r	r
ல்	l	l
ள்	ḷ	ɭ
வ்	v	ʋ
ழ்	l̲	ɻ

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