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Metrical prominence asymmetries in Medumba, a Grassfields Bantu language: Supplementary material

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METRICAL PROMINENCE ASYMMETRIES IN MEDUMBA, A GRASSFIELDS BANTU LANGUAGE
ONLINE SUPPLEMENTAL MATERIALS

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1. DATA POINTS ANALYZED BY SUBJECT, SET, METRONOME SPEED, AND CONDITION. Tables S1–S2 provide details of how many metronome speeds were attainable for each subject across Sets A–C in Experiments 1 and 2. Table S3 indicates the number of data points analyzed for each prosodic form condition across the two experiments.

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13
Set A	9	15	14	12	14	13	9	10	6	14	11	11	13
Set B	7	14	12	12	12	10	6	9	5	13	8	10	11
Set C	8	14	12	12	12	11	8	6	5	12	10	9	10

TABLE S1. Number of metronome speeds attainable for sentence repetitions by Subject (s) and Set, Experiment 1.

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14
Set A	8	14	15	15	13	10	15	13	15	15	14	14	10	15
Set B	13	14	15	13	13	9	14	15	13	15	15	13	12	15
Set C	14	12	15	13	15	11	15	15	14	15	14	15	12	12

TABLE S2. Number of metronome speeds attainable for sentence repetitions by Subject (s) and Set, Experiment 2.

Experiment/Prosodic Condition	Syllable 3	Syllable 4
Experiment 1, SISF	2295	2300
Experiment 1, SISI	2259	2289
Experiment 2, PreSI	2927	2938
Experiment 2, SIEnc	2975	3021

TABLE S3. Total data points analyzed by experiment and prosodic condition.

2. DERIVING THE NUMBER OF COMPONENT DISTRIBUTIONS. Table S4 provides results from the parametric bootstrap procedure utilized to determine the optimal number of components in each mixture distribution. The parametric bootstrap works by iteratively resampling the data with replacement, fitting models to these samples, and optimizing over model parameter values to arrive at the most likely model to account for the data set. For choosing the component number of a Gaussian mixture, the procedure generates *B* bootstrap realizations of the likelihood ratio

statistic for testing the null hypothesis of a model with k components versus the alternative of a model with $k+1$ components (from 1 up to a possible 10 components, in our case). Results for the bootstrap procedure are provided in Table S4. Decisions about the number of components for each distribution were made primarily based on the results of the bootstrap procedure: if the difference between the fits of two models was not significant below the $p = .05$ level, then the model with fewer components was chosen. However, in some cases (as with Syllable 3 in the Pre-SI and SI-Enc conditions and Syllable 4 in the SISF and SI-Enc conditions), despite a significant difference between models according to the bootstrap procedure, visual inspection revealed that an additional component would account for a negligible amount of data (below 1%) in the model. In such cases, the model with fewer components was still chosen.

	Condition	Choice of K	$K = 1$ vs. $K = 2$		$K = 2$ vs. $K = 3$		$K = 3$ vs. $K = 4$		$K = 4$ vs. $K = 5$	
			Observed LRS	p -value	Observed LRS	p -value	Observed LRS	p -value	Observed LRS	p -value
Expt 1	Syllable 3, SISF	3	181.15	<.005	36.01	<.005	8.25	=.11	N/A	N/A
	Syllable 3, SISI	3	290.09	<.005	28.12	<.005	10.64	=.07	N/A	N/A
	Syllable 4, SISF	3	172.12	<.005	33.61	<.005	22.60	=.02	N/A	N/A
	Syllable 4, SISI	3	200.17	<.005	32.45	<.005	8.27	=.10	N/A	N/A
Expt 2	Syllable 3, Pre-SI	2	401.14	<.005	54.53	=.01	N/A	N/A	N/A	N/A
	Syllable 3, SI-Enc	2	273.09	<.005	1.97	=.01	N/A	N/A	N/A	N/A
	Syllable 4, Pre-SI	3	320.33	<.005	80.53	<.0001	9.80	=.05	N/A	N/A
	Syllable 4, SI-Enc	3	199.16	<.005	16.31	<.005	41.77	=.01	N/A	N/A

TABLE S4. Choice of GMM component number K based on parametric bootstrap of log-likelihood ratio statistics.

3. RESULTS OF 3-FOLD CROSS-VALIDATION. Tables S5–S8 provide results from the 3-fold cross-validation procedure used to determine optimal model parameters and generalizability across the data sets. Parameters from each model generated within the procedure are provided for each syllable and prosodic form, along with log likelihood of the model, and Chi-Square results evaluating goodness of fit between the model and corresponding testing data.

Condition	Model	mean μ			Standard deviation σ			Mixing proportion λ			Log likelihood	Chi-Square, train vs. test
Syl. 3, SISI	1	.34	.43	.53	.04	.04	.04	.71	.21	.08	1940.84	$X^2(1, N = 749)$ $= 8.35, p = .77$
	2	.34	.43	.55	.04	.04	.03	.68	.27	.05	1969.42	$X^2(1, N = 749)$ $= 18.51, p = .07$
	3	.34	.44	.54	.04	.03	.04	.77	.16	.07	1979.23	$X^2(1, N = 749)$ $= 14.37, p = .20$
Syl. 3, SISF	1	.34	.44	.54	.05	.06	.09	.62	.32	.05	1716.37	$X^2(1, N = 762)$ $= 14.37, p = .20$
	2	.34	.45	.44	.05	.05	.11	.60	.22	.18	1712.84	$X^2(1, N = 760)$ $= 3.71, p = .95$
	3	.34	.43	.56	.05	.07	.08	.56	.40	.04	1716.40	$X^2(1, N = 761)$ $= 4.68, p = .89$
Syl. 4, SISI	1	.42	.51	.70	.04	.07	.04	.22	.73	.05	1697.68	$X^2(1, N = 759)$ $= 24.14, p < .05$
	2	.41	.49	.61	.03	.06	.08	.14	.68	.18	1655.16	$X^2(1, N = 759)$ $= 8.21, p = .71$
	3	.42	.50	.59	.04	.05	.08	.29	.45	.26	1683.40	$X^2(1, N = 759)$ $= 11.08, p = .38$
Syl. 4, SISF	1	.41	.52	.54	.05	.05	.11	.49	.27	.24	1528.83	$X^2(1, N = 762)$ $= 5.41, p = .83$
	2	.41	.53	.55	.05	.05	.11	.51	.27	.21	1529.87	$X^2(1, N = 764)$ $= 10.61, p = .34$
	3	.40	.53	.69	.06	.05	.05	.58	.36	.05	1499.57	$X^2(1, N = 762)$ $= 9.07, p = .70$

TABLE S5. Experiment 1: Model parameters derived using 3-fold cross-validation, means unspecified.

Condition	Model	mean μ			Standard deviation σ			Mixing proportion λ			Log likelihood	Chi-Square, train vs. test
Syl. 3, SISI	1	.33	.50	.67	.05	.06	.23	.81	.18	.01	1858.29	$X^2(1, N = 749) = 111.74, p < .001$
	2	.33	.50	.67	.05	.06	.23	.81	.18	.01	1867.28	$X^2(1, N = 749) = 83.35, p < .001$
	3	.33	.50	.67	.05	.06	.23	.82	.18	.01	1878.00	$X^2(1, N = 749) = 81.22, p < .001$
Syl. 3, SISF	1	.33	.50	.67	.06	.07	.13	.72	.27	.01	1628.44	$X^2(1, N = 762) = 77.37, p < .001$
	2	.33	.50	.67	.06	.06	.04	.72	.27	.01	1619.78	$X^2(1, N = 760) = 84.30, p < .001$
	3	.33	.50	.67	.05	.07	.15	.71	.28	.01	1630.20	$X^2(1, N = 761) = 100.47, p < .001$
Syl. 4, SISI	1	.33	.50	.67	.05	.07	.06	.01	.94	.05	1640.99	$X^2(1, N = 759) = 51.25, p < .001$
	2	.33	.50	.67	.04	.08	.07	.01	.94	.05	1607.31	$X^2(1, N = 759) = 51.44, p < .001$
	3	.33	.50	.67	.05	.06	.08	.01	.94	.05	1633.60	$X^2(1, N = 759) = 51.28, p < .001$
Syl. 4, SISF	1	.33	.50	.67	.04	.09	.11	.08	.91	.01	1413.70	$X^2(1, N = 762) = 114.40, p < .001$
	2	.33	.50	.67	.04	.09	.11	.09	.90	.01	1419.96	$X^2(1, N = 764) = 132.57, p < .001$
	3	.33	.50	.67	.04	.09	.10	.08	.91	.01	1386.44	$X^2(1, N = 762) = 113.12, p < .001$

TABLE S6. Experiment 1: Model parameters derived using 3-fold cross-validation, means specified.

Condition	Model	mean μ			Standard deviation σ			Mixing proportion λ			Log prob.	Chi-Square, train vs. test
Syl. 3, SIEnc	1	.32	.46		.06	.06		.76	.24		2180.07	$X^2(1, N = 987) = 10.25, p = .75$
	2	.31	.43		.05	.08		.63	.37		2169.95	$X^2(1, N = 988) = 20.64, p < .05$
	3	.31	.41		.05	.08		.54	.46		2209.49	$X^2(1, N = 988) = 19.93, p = .05$
Syl. 3, PreSI	1	.28	.37		.05	.08		.74	.26		2546.18	$X^2(1, N = 971) = 18.94, p = .12$
	2	.28	.38		.05	.08		.76	.24		2542.05	$X^2(1, N = 972) = 21.07, p = .05$
	3	.28	.37		.05	.08		.77	.23		2543.46	$X^2(1, N = 972) = 31.84, p < .01$
Syl. 4, SIEnc	1	.38	.49	.62	.03	.06	.11	.09	.49	.42	1620.06	$X^2(1, N = 1003) = 13.90, p = .30$
	2	.39	.50	.61	.04	.05	.11	.15	.41	.44	1602.59	$X^2(1, N = 1003) = 24.19, p < .05$
	3	.37	.49	.68	.02	.07	.09	.06	.69	.25	1624.12	$X^2(1, N = 1003) = 17.39, p = .13$
Syl. 4, PreSI	1	.39	.49	.59	.04	.05	.11	.27	.40	.33	1691.20	$X^2(1, N = 975) = 14.03, p = .29$
	2	.38	.49	.63	.04	.06	.11	.21	.56	.23	1694.15	$X^2(1, N = 976) = 15.47, p = .20$
	3	.38	.48	.67	.04	.07	.09	.16	.67	.17	1698.04	$X^2(1, N = 975) = 12.60, p = .41$

TABLE S7. Experiment 2: Model parameters derived using 3-fold cross-validation, means specified.

Condition	Model	mean μ			Standard deviation σ			Mixing proportion λ			Log prob.	Chi-Square, train vs. test
Syl. 3, SIEnc	1	.33	.50		.06	.04		.86	.14		2169.97	$X^2(1, N = 987) = 16.94, p = .39$
	2	.33	.50		.05	.08		.86	.14		2109.49	$X^2(1, N = 988) = 151.14, p < .001$
	3	.33	.50		.06	.05		.86	.14		2190.02	$X^2(1, N = 988) = 24.00, p < .05$
Syl. 3, PreSI	1	.33	.50		.07	.30		.99	.01		2282.95	$X^2(1, N = 971) = 307.83, p < .001$
	2	.33	.50		.08	.15		.99	.01		2257.06	$X^2(1, N = 972) = 300.44, p < .001$
	3	.33	.50		.08	.31		.99	.01		2269.71	$X^2(1, N = 972) = 305.61, p < .001$
Syl. 4, SIEnc	1	.33	.50	.67	.03	.08	.10	.01	.78	.21	1581.78	$X^2(1, N = 1003) = 31.23, p < .01$
	2	.33	.50	.67	.05	.08	.10	.01	.79	.20	1573.23	$X^2(1, N = 1003) = 46.38, p < .01$
	3	.33	.50	.67	.02	.08	.10	.01	.78	.21	1584.03	$X^2(1, N = 1003) = 46.42, p < .001$
Syl. 4, PreSI	1	.33	.50	.67	.02	.09	.11	.05	.86	.09	1691.20	$X^2(1, N = 975) = 72.88, p < .001$
	2	.33	.50	.67	.02	.08	.11	.05	.85	.10	1616.62	$X^2(1, N = 976) = 89.15, p < .001$
	3	.33	.50	.67	.03	.08	.10	.05	.84	.11	1607.23	$X^2(1, N = 975) = 60.90, p < .001$

TABLE S8. Experiment 2: Model parameters derived using 3-fold cross-validation, means specified.

4. COMPONENT COMPOSITION BY SUBJECT AND METRONOME SPEED. Tables S9–S12 provide details for the final Gaussian Mixture Models on the constitution of each cluster by subject and by metronome speed. We note that clustering of data was not determined primarily by subject: Tables S9 and S11 show that data from nearly all subjects was present in each component of each model. However, as predicted, component composition was determined by metronome speed: Tables S10 and S12 show that Component 1 across models tended to be composed of data from lower metronome speeds, while higher component numbers were populated with data from higher metronome speeds. Thus, we can conclude that shifts in alignment position throughout the task were driven by changes in speaking rate.

Experiment 1, Syllable 3, SISI													
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13
1	133	127	162	166	168	122	121	99	91	74	138	102	140
2	4	69	41	48	45	74	0	27	2	47	33	36	38
3	0	42	1	2	8	12	0	6	0	61	1	17	2
Experiment 1, Syllable 3, SISF													
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13
1	136	144	135	146	176	128	130	96	91	48	124	101	133
2	2	72	65	65	47	73	0	38	5	56	33	56	40
3	0	29	11	5	3	3	0	4	0	66	13	19	2
Experiment 1, Syllable 4, SISI													
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13
1	44	22	3	16	28	6	21	10	11	1	29	1	14
2	99	150	206	182	172	167	101	114	82	95	144	135	161
3	0	61	6	24	19	34	0	24	0	68	7	27	5
Experiment 1, Syllable 4, SISF													
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13
1	134	121	110	120	133	85	125	78	85	15	99	91	116
2	4	82	83	79	77	106	2	52	11	84	48	54	59
3	0	42	23	16	6	10	0	19	0	81	17	28	5

TABLE S9. Component composition by subject, Experiment 1.

Experiment 1, Syllable 3, SISI															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	196	211	207	205	197	180	145	118	86	47	26	18	2	5	0
2	1	4	15	10	22	24	44	64	57	77	67	47	18	14	0
3	0	0	0	0	0	1	2	4	19	26	22	25	28	19	6
Experiment 1, Syllable 3, SISF															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	194	203	220	210	199	167	126	94	62	51	37	11	9	5	0
2	1	1	7	10	22	51	63	77	86	75	56	56	24	19	4
3	4	0	1	0	2	0	3	20	20	23	23	26	19	12	2
Experiment 1, Syllable 4, SISI															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	68	59	42	25	4	5	2	0	0	0	1	0	0	0	0
2	134	156	185	187	216	194	177	169	136	105	76	49	18	6	0
3	0	0	1	0	1	3	13	15	33	42	42	53	38	28	6
Experiment 1, Syllable 4, SISF															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	198	202	206	203	172	138	94	56	31	7	2	1	1	1	0
2	5	14	15	17	48	78	85	110	106	97	79	48	23	16	0
3	3	0	1	1	4	0	8	20	33	46	42	42	23	18	6

TABLE S10. Component composition by metronome speed, Experiment 1.

Experiment 2, Syllable 3, SIEnc														
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14
1	167	177	231	228	201	146	138	89	152	107	152	93	186	209
2	23	57	9	24	27	16	30	77	95	138	94	55	12	42
Experiment 2, Syllable 3, PreSI														
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14
1	177	183	237	219	197	141	134	116	168	123	164	122	185	237
2	4	50	0	33	31	20	27	51	72	112	81	30	1	12
Experiment 2, Syllable 4, SIEnc														
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14
1	45	18	49	33	50	7	1	1	12	0	29	8	33	34
2	110	122	190	154	144	120	102	63	137	88	110	65	140	168
3	35	94	18	77	34	29	65	101	104	157	113	86	25	50
Experiment 2, Syllable 4, PreSI														
Component	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14
1	79	40	62	51	60	1	10	18	21	4	42	20	57	27
2	110	171	186	184	149	134	147	93	160	124	141	91	135	214
3	3	23	1	17	19	6	27	51	53	91	62	45	0	9

TABLE S11. Component composition by subject, Experiment 2.

Experiment 2, Syllable 3, SIENC															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	221	223	234	228	227	218	185	184	143	130	99	81	61	32	10
2	0	0	0	0	7	15	32	41	74	86	109	110	110	66	49
Experiment 2, Syllable 3, PRESI															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	216	219	234	226	227	228	200	201	185	156	114	89	60	39	9
2	0	1	0	0	1	2	12	23	34	53	82	104	106	56	50
Experiment 2, Syllable 4, SIENC															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	114	100	72	20	9	1	2	2	0	0	0	0	0	0	0
2	104	118	161	199	208	204	170	162	129	89	67	51	24	16	11
3	3	5	1	3	17	28	45	64	94	127	142	140	153	99	67
Experiment 2, Syllable 4, PRESI															
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	151	150	102	51	24	11	0	0	1	1	1	0	0	0	0
2	67	71	126	177	203	212	217	225	193	164	146	116	68	39	15
3	0	0	0	0	0	1	0	4	20	38	63	77	97	57	50

TABLE S12. Component composition by metronome speed, Experiment 2.