

## Intelligibility of high-pitched vowel sounds in the singing and speaking of a female Cantonese Opera singer

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**Table 1: Vowel sounds and syllables investigated, and results of the listening test.** For each of the sounds investigated, the table indicates: F0 (average of the center of the vowel sound), the intended vowel, the corresponding syllable or vowel sound produced in isolation, the perceived vowel qualities in percent, the duration of the entire sound and the analysed time segment of the vowel nucleus (center of vowel sound), the maximum and minimum of F0 (vowel nucleus) and the archive number of the sound. For sounds marked in grey, their identification rate proved to be  $\leq 50\%$  according to the intended vowel of the singer. (Note, that rare identifications of /ɛ/ are not included in the identification rates given; thus, for some sounds, the total of the identification rate is not 100%.)

F0 (average) of vowel sound	Vowel intended	Syllable of vowel Jyutping notation	Identification						Duration		Range of F0 of vowel sound (nucleus)		Sound number
			/i/	/y/	/œ/	/a/	/ɔ/	/u/	syllable	vowel nucleus	max.	min.	
587	i	gip3	84.6	15.4	0	0	0	0	2.39	1.91	757	447	110452
616	i	jín1	80.8	19.2	0	0	0	0	0.6	0.28	653	584	110474
617	i	siu2	61.5	19.2	19.2	0	0	0	0.44	0.08	661	561	109717
625	i	ci3	100	0	0	0	0	0	0.56	0.3	653	605	110397
626	i	bin1	80.8	19.2	0	0	0	0	0.47	0.23	707	519	110124
626	i	zip3	96.2	3.8	0	0	0	0	1.15	0.59	648	601	109735
627	i	tin1	80.8	19.2	0	0	0	0	1.82	0.47	644	604	110084
627	i	ci1	57.7	42.3	0	0	0	0	0.42	0.34	682	597	110571
628	i	tin1	88.5	7.7	3.8	0	0	0	0.94	0.52	655	613	110401
632	i	sin1	96.2	3.8	0	0	0	0	1.01	0.52	650	607	110585
632	i	git3	92.3	3.8	0	0	0	0	0.56	0.36	661	599	110367
633	i	din2	100	0	0	0	0	0	1.66	0.56	715	575	110188
633	i	zim1	88.5	7.7	0	0	0	3.8	0.63	0.27	651	614	109737
634	i	sin1	92.3	3.8	0	0	0	0	1.28	0.74	691	605	110739
634	i	dim3	100	0	0	0	0	0	0.5	0.21	682	611	109731
638	i	jín1	92.3	3.8	0	0	0	3.8	0.41	0.19	677	610	109756
642	i	liu3	88.5	11.5	0	0	0	0	1.35	0.47	676	617	110408
642	i	zi2	100	0	0	0	0	0	1.27	0.56	725	592	110712
646	i	pin1	84.6	15.4	0	0	0	0	0.29	0.21	687	622	109824
646	i	pin1	88.5	11.5	0	0	0	0	0.77	0.5	676	562	109825
648	i	zi2	92.3	7.7	0	0	0	0	0.77	0.24	673	609	110333
654	i	i	80.8	19.2	0	0	0	0	1.3	1.1	717	567	109997
665	i	zi2	84.6	7.7	0	0	0	7.7	0.44	0.36	843	578	110637
666	i	zi2	88.5	3.8	0	0	0	3.8	0.69	0.34	747	606	110705
666	i	ji1	92.3	7.7	0	0	0	0	0.65	0.46	713	572	109994
669	i	ci1	96.2	0	0	0	0	0	0.72	0.14	689	648	110205
670	i	ci2	92.3	7.7	0	0	0	0	1.5	0.52	689	612	109922
674	i	dim	80.8	3.8	11.5	3.8	0	0	0.48	0.16	688	655	110313
674	i	pin1	100	0	0	0	0	0	0.43	0.22	746	570	110240
675	i	ji3	76.9	15.4	0	0	3.8	3.8	0.52	0.32	691	648	110095
675	i	ji1	88.5	7.7	3.8	0	0	0	0.73	0.25	696	634	110155
676	i	li	100	0	0	0	0	0	0.28	0.06	701	639	109703
679	i	bin2	96.2	3.8	0	0	0	0	1.3	0.89	724	638	110219
682	i	li1	80.8	3.8	0	7.7	0	7.7	0.36	0.2	704	619	109774
683	i	si6	92.3	7.7	0	0	0	0	0.58	0.3	699	660	110290
685	i	pin1	88.5	11.5	0	0	0	0	0.42	0.12	710	643	110239
687	i	jín4	73.1	15.4	7.7	0	3.8	0	1.7	1.09	873	576	110315
689	i	i	92.3	7.7	0	0	0	0	0.3	0.28	717	644	110000
689	i	tin1	80.8	19.2	0	0	0	0	1.25	0.75	778	619	110493
690	i	i	38.5	46.2	11.5	0	0	3.8	0.57	0.25	707	676	109998
692	i	ci1	80.8	15.4	0	0	0	0	0.53	0.21	717	673	109972
693	i	jim1	69.2	26.9	0	0	0	3.8	0.44	0.13	727	648	110265
696	i	zi2	88.5	11.5	0	0	0	0	1.48	0.69	828	634	110082
697	i	min6	88.5	3.8	7.7	0	0	0	0.92	0.51	746	666	109799
698	i	cin1	84.6	0	7.7	0	0	3.8	0.31	0.15	735	640	109934
699	i	zi1	96.2	3.8	0	0	0	0	0.48	0.29	737	672	109757
700	i	jim1	96.2	3.8	0	0	0	0	0.45	0.07	712	684	110264
701	i	cim1	100	0	0	0	0	0	0.44	0.13	733	648	110153
701	i	ci2	84.6	11.5	3.8	0	0	0	0.66	0.21	758	652	110068
702	i	zim1	73.1	26.9	0	0	0	0	0.46	0.14	734	643	109961
711	i	cin1	100	0	0	0	0	0	1.07	0.52	753	683	110353
713	i	sin1	61.5	3.8	30.8	0	0	3.8	0.29	0.1	735	642	110324
714	i	si1	92.3	7.7	0	0	0	0	6.21	4.5	843	609	110677
716	i	jip6	92.3	0	3.8	0	0	3.8	1.14	0.6	770	670	110691
731	i	gip3	61.5	7.7	3.8	26.9	0	0	0.31	0.11	779	673	110606

737	i	ziu1	69.2	15.4	11.5	0	0	3.8	1.82	1.22	887	632	110371
747	i	liu5	80.8	11.5	3.8	3.8	0	0	0.72	0.41	857	674	110314
750	i	ci1	100	0	0	0	0	0	0.33	0.13	824	705	110635
751	i	ci1	96.2	3.8	0	0	0	0	1.27	1.04	838	590	110706
791	i	ji5	73.1	26.9	0	0	0	0	3	2.5	923	684	110703
858	i	sin1	92.3	3.8	0	3.8	0	0	0.39	0.12	887	784	110648
F0 (average) of vowel sound	Vowel intended	Syllable of vowel	Identification						Duration		Range of F0 of vowel sound (nucleus)		Sound number
			Jyutping notation	/i/	/y/	/œ/	/a/	/ɔ/	/u/	syllable	vowel nucleus	max.	
597	y	dyun2	0	92.3	7.7	0	0	0	1.55	0.59	636	538	110179
621	y	jyu5	30.8	65.4	3.8	0	0	0	0.35	0.32	675	594	110610
627	y	syu1	34.6	57.7	0	0	0	7.7	0.68	0.33	647	614	110220
649	y	nyun5	7.7	84.6	7.7	0	0	0	0.45	0.18	751	538	110312
667	y	jyun4	3.8	69.2	23.1	0	0	0	2.05	0.47	707	638	110079
680	y	syun1	3.8	84.6	7.7	0	0	3.8	0.82	0.46	717	611	109895
682	y	jyun1	80.8	19.2	0	0	0	0	0.41	0.24	713	611	110112
692	y	zyun2	0	88.5	7.7	0	0	3.8	1.94	1.1	789	605	110489
774	y	jyun4	38.5	61.5	0	0	0	0	1.44	0.4	817	656	110292
F0 (average) of vowel sound	Vowel intended	Syllable of vowel	Identification						Duration		Range of F0 of vowel sound (nucleus)		Sound number
			Jyutping notation	/i/	/y/	/œ/	/a/	/ɔ/	/u/	syllable	vowel nucleus	max.	
630	œ	joek6	0	0	88.5	11.5	0	0	0.8	0.48	650	601	110357
650	œ	zoeng1	0	3.8	96.2	0	0	0	0.43	0.18	712	552	109728
650	œ	soeng2	0	0	100	0	0	0	2.11	0.78	710	624	109793
660	œ	soeng1	0	0	100	0	0	0	0.64	0.34	688	573	110104
684	œ	soeng1	7.7	0	92.3	0	0	0	0.77	0.57	697	654	109890
685	œ	zoe	0	34.6	65.4	0	0	0	0.26	0.12	712	639	109727
694	œ	joeng1	7.7	19.2	73.1	0	0	0	0.65	0.41	741	635	110113
737	œ	soeng1	11.5	3.8	80.8	3.8	0	0	0.44	0.21	793	697	110216
762	œ	zoeng1	0	0	100	0	0	0	1.2	0.99	801	741	109913
765	œ	soe	0	0	96.2	3.8	0	0	1	0.73	809	745	109724

F0 (average) of vowel sound	Vowel intended	Syllable of vowel Jyutping notation	Identification						Duration		Range of F0 of vowel sound (nucleus)		Sound number
			/i/	/y/	/œ/	/a/	/ɔ/	/u/	syllable	vowel nucleus	max.	min.	
562	a	saan3	0	0	0	100	0	0	1.78	1.23	635	528	110463
571	a	saan3	0	0	0	100	0	0	2.28	1.87	646	547	110512
573	a	faa1	0	0	0	96.2	0	3.8	0.51	0.27	632	527	110178
582	a	saang1	0	0	0	100	0	0	0.8	0.34	654	511	109784
602	a	zaam6	3.8	0	0	92.3	0	3.8	0.35	0.16	756	480	110662
606	a	caam1	0	0	26.9	73.1	0	0	1.97	1	654	558	110497
614	a	baa6	0	0	0	100	0	0	0.82	0.53	654	574	110618
617	a	faa1	0	0	0	100	0	0	0.93	0.35	669	580	110462
617	a	haak3	0	0	7.7	92.3	0	0	0.64	0.34	631	594	109804
621	a	taan3	0	0	0	96.2	0	3.8	0.27	0.09	723	553	110663
623	a	faa1	3.8	0	23.1	73.1	0	0	0.34	0.14	644	546	110273
623	a	waan3	0	0	0	100	0	0	1.08	0.56	735	560	110611
628	a	taa1	0	0	0	100	0	0	0.37	0.18	639	610	110011
629	a	faa1	0	0	0	100	0	0	0.77	0.48	753	528	110421
633	a	haak3	0	0	3.8	96.2	0	0	0.5	0.19	665	615	109733
634	a	saam1	0	0	7.7	92.3	0	0	1.03	0.75	697	603	109830
636	a	faa1	3.8	0	0	92.3	3.8	0	0.3	0.12	673	618	110261
638	a	saan3	0	0	0	100	0	0	4.25	2	680	610	110373
648	a	saam1	0	0	0	100	0	0	0.62	0.28	720	561	110101
651	a	faa1	0	0	0	100	0	0	0.95	0.3	681	599	110138
652	a	taa1	0	0	7.7	92.3	0	0	0.65	0.26	713	522	110266
655	a	gaan1	0	0	15.4	23.1	53.8	7.7	1.61	1.1	757	544	110473
658	a	gaa1	0	0	0	96.2	0	0	0.38	0.15	700	618	110336
659	a	caam2	0	0	0	100	0	0	0.69	0.34	713	453	110396
661	a	gaan1	0	0	3.8	96.2	0	0	1.4	0.96	768	581	110544
667	a	faa1	0	0	0	100	0	0	1.88	1.31	761	609	110526
672	a	aa	0	0	0	100	0	0	1.28	0.62	718	625	110043
677	a	haau1	0	0	11.5	88.5	0	0	1.56	0.84	759	608	110549
679	a	aa	0	0	3.8	96.2	0	0	0.5	0.49	704	654	110063
680	a	gaan1	0	0	11.5	88.5	0	0	0.66	0.29	705	661	110341
681	a	faa1	0	0	0	100	0	0	0.61	0.36	841	496	110424
681	a	faa1	0	0	0	100	0	0	0.34	0.12	744	614	110268
683	a	faa1	0	0	0	96.2	0	3.8	0.6	0.28	696	677	110307
684	a	faa1	0	0	0	100	0	0	0.92	0.29	706	656	109966
686	a	faa1	0	0	0	100	0	0	0.42	0.21	724	675	110331
687	a	laap6	0	0	0	100	0	0	0.37	0.15	712	678	110049
688	a	aa	0	0	0	100	0	0	3.96	1.8	699	674	110746
701	a	saam1	0	0	0	100	0	0	0.94	0.42	720	687	110368
702	a	faa1	0	0	3.8	96.2	0	0	4.07	2.13	789	651	110686
708	a	faan1	0	0	0	100	0	0	0.58	0.34	777	597	110478
752	a	saam1	0	0	26.9	73.1	0	0	1.19	0.63	798	727	110352
760	a	gaan1	0	0	23.1	73.1	0	3.8	0.57	0.16	767	752	110492
768	a	faa1	0	0	0	100	0	0	2.4	1.9	903	662	110527
768	a	faan	0	0	11.5	88.5	0	0	0.7	0.41	906	712	110609
819	a	faa1	0	0	0	100	0	0	1.57	0.6	882	702	110682
823	a	saam1	0	0	11.5	84.6	0	3.8	0.39	0.14	852	792	110328

F0 (average) of vowel sound	Vowel intended	Syllable of vowel	Identification						Duration		Range of F0 of vowel sound (nucleus)		Sound number
			Jyutping notation	/i/	/y/	/œ/	/a/	/ɔ/	/u/	syllable	vowel nucleus	max.	
562	c	long6	0	0	0	0	65.4	34.6	1.55	0.28	586	517	110480
615	c	gon1	0	3.8	19.2	0	7.7	69.2	0.3	0.1	659	572	110198
615	c	dong1	0	0	0	0	100	0	0.69	0.36	672	526	110636
624	c	ceot1	0	0	23.1	0	76.9	0	0.66	0.42	642	586	110445
625	c	gong	15.4	0	3.8	0	57.7	23.1	0.67	0.35	686	606	110389
627	c	hong1	0	0	11.5	11.5	61.5	15.4	2.96	0.69	649	602	110075
628	c	o	0	0	15.4	3.8	80.8	0	1.03	0.87	650	601	109751
629	c	gwong2	0	0	0	0	57.7	42.3	0.52	0.33	759	597	110438
632	c	gwo3	0	0	3.8	3.8	61.5	30.8	1.07	0.63	664	609	109803
634	c	fong1	0	0	3.8	0	92.3	3.8	0.7	0.51	661	607	109886
637	c	o	0	0	0	0	100	0	0.55	0.53	652	622	110034
649	c	on1	0	0	3.8	0	92.3	3.8	1.33	0.99	771	586	109868
649	c	ho2	0	0	0	0	11.5	88.5	0.56	0.33	738	550	109975
650	c	wong3	0	0	0	0	96.2	3.8	0.88	0.38	687	621	110405
654	c	do1	0	0	3.8	0	34.6	61.5	0.3	0.11	702	593	109712
655	c	go1	0	0	0	0	50	50	2.82	2.01	765	601	110516
671	c	mong6	0	0	3.8	3.8	92.3	0	0.7	0.56	700	624	109764
684	c	go2	0	0	3.8	7.7	84.6	3.8	0.31	0.09	841	580	109939
685	c	go1	0	0	3.8	0	15.4	80.8	0.74	0.5	739	655	110515
694	c	o	0	0	0	0	100	0	0.5	0.25	715	679	110121
698	c	ho2	0	0	7.7	7.7	84.6	0	0.31	0.14	894	592	110670
710	c	ho	0	0	3.8	0	34.6	61.5	0.21	0.1	726	679	109725
732	c	gok3	0	0	0	0	100	0	3.39	2.8	862	599	110413
733	c	do1	0	0	0	3.8	96.2	0	1.12	0.88	898	644	110347
771	c	bo1	0	0	0	0	34.6	65.4	0.78	0.39	847	733	110477
836	c	zo	0	0	11.5	0	69.2	19.2	0.58	0.41	899	759	110033
845	c	fong1	0	0	0	0	88.5	11.5	4.18	0.51	868	825	110737
F0 (average) of vowel sound	Vowel intended	Syllable of vowel	Identification						Duration		Range of F0 of vowel sound (nucleus)		Sound number
		Jyutping notation	/i/	/y/	/œ/	/a/	/ɔ/	/u/	syllable	vowel nucleus	max.	min.	
626	u	u	0	0	0	0	50	50	0.34	0.32	659	528	110567
630	u	gun2	0	0	0	0	7.7	92.3	0.53	0.16	680	528	110499
636	u	u	0	0	3.8	0	0	96.2	0.3	0.3	682	545	110742
641	u	mun5	0	0	0	0	0	100	2.2	1.27	690	606	110376
641	u	fung4	0	0	0	7.7	92.3	0	0.29	0.13	694	620	110289
660	u	fun1	0	0	0	0	0	100	2.69	1.88	821	545	110534
675	u	gun2	0	0	3.8	0	0	96.2	0.86	0.32	785	585	110505
683	u	pun1	0	0	3.8	0	38.5	57.7	1.25	0.31	754	624	109867
687	u	fun1	0	0	0	0	0	100	1.58	1.21	857	541	110504
691	u	fu1	0	7.7	3.8	0	3.8	84.6	0.58	0.3	766	593	109951
691	u	gun1	0	0	3.8	0	0	96.2	0.82	0.51	738	634	110366
694	u	pun1	0	0	0	15.4	50	34.6	0.76	0.5	731	641	109750
697	u	guk1	0	0	0	7.7	65.4	26.9	0.27	0.05	713	678	110302
698	u	pun1	0	0	0	0	19.2	80.8	0.49	0.18	725	644	110109
741	u	mun5	0	0	0	0	3.8	96.2	2.09	0.81	815	591	110472
760	u	u	3.8	0	0	0	15.4	80.8	0.65	0.63	815	706	110466
790	u	mun5	0	0	0	0	11.5	88.5	0.98	0.33	855	668	110692
855	u	fu1	3.8	0	7.7	0	7.7	80.8	0.45	0.23	873	827	109789