Maurer, D., Suter, H.: "Flat" vowel spectra revisited in vowel synthesis. Journal of the Acoustical Society of America, 141(5):3469–3469.

Details of the listening test and entire tables of the corresponding results (confusion matrices).

Vowel recognition was investigated by means of a listening test: five phonetic expert listeners assigned the synthesised sounds to Standard German vowel qualities or to “no vowel” (ns = not specified). Subtests corresponding to the single tables shown below were performed, separated with a pause of 10 min. at a minimum. The results are presented below in terms of confusion matrices.

Experiment 1: Increasing the number of harmonics stepwise from H1 to H1–H20.														
Harmonics		Results of the listening test (5 listeners)											Frequency range	
Numbers		Confusion matrix										Majority	kHz	
	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns	4/5 and 5/5		
Extension of harmonic series	1-20					**4**		1				**ɛ**	Frequency bands	0.2–4
	1-19					**3**		2				**ɛ**		0.2–3.8
	1-18					**4**		1				**ɛ**		0.2–3.6
	1-17					**4**		1				**ɛ**		0.2–3.4
	1-16					**4**		1				**ɛ**		0.2–3.2
	1-15					**4**		1				**ɛ**		0.2–3
	1-14					**3**	1	1				**ɛ**		0.2–2.8
	1-13					**5**						**ɛ**		0.2–2.6
	1-12					**3**	2					**ɛ**		0.2–2.4
	1-11					**4**	1					**ɛ**		0.2–2.2
	1-10				1	2	2							0.2–2
	1-9			1	2		1				1			0.2–1.8
	1-8				**5**							**a**		0.2–1.6
	1-7				**5**							**a**		0.2–1.4
	1-6			1	**4**							**a**		0.2–1.2
	1-5			**4**	1							**ɔ**		0.2–1
	1-4		2	**3**								**ɔ**		0.2–0.8
	1-3	1	**3**	1								**o**		0.2–0.6
	1-2	2	**3**									**o**		0.2–0.4
	1 (only)	**5**										**u**		0.2 only

Experiment 2: Decreasing the number of harmonics stepwise from H1–H20 to H20 only.														
Harmonics		Results of the listening test (5 listeners)											Frequency range	
Numbers		Confusion matrix										Majority	kHz	
	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
Extension of harmonic series	20 (only)									**4**	1	**i**	Frequency bands	4 only
	19-20									**5**		**i**		3.8–4
	18-20								1	**4**		**i**		3.6–4
	17-20									**5**		**i**		3.4–4
	16-20							2		**3**		**i**		3.2–4
	15-20							2		**3**		**i**		3–4
	14-20							2	1	2				2.8–4
	13-20							**3**	1	1		**e**		2.6–4
	12-20							**3**	1	1		**e**		2.4–4
	11-20							2	1	1	1			2.2–4
	10-20					1	2		1	1				2–4
	9-20				1		1	1	1		1			1.8–4
	8-20				2	1		2						1.6–4
	7-20				**4**						1	**a**		1.4–4
	6-20				**4**						1	**a**		1.2–4
	5-20				2	**3**						**ɛ**		1–4
	4-20			2		**3**						**ɛ**		0.8–4
	3-30			2	1	2								0.6–4
	2-20		1		1	1	2							0.4–4
	1-20			1	1	2					1			0.2–4

Experiment 3: Increasing the number of harmonics stepwise from a middle harmonic to a band of higher harmonics.

Harmonics	Results of the listening test (5 listeners)												Frequency
Numbers	Confusion matrix										Majority		kHz
H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
1-11													0.2–2.2
1-10				1	2	2						Frequency bands	0.2–2
1-9			1	2		1				1			0.2–1.8
1-8				**5**							**a**		0.2–1.6
1-7				**5**							**a**		0.2–1.4
1-6			1	**4**							**a**		0.2–1.2
1-5			**4**	1							**ɔ**		0.2–1
1-4		2	**3**								**ɔ**		0.2–0.8
1-3	1	**3**	1								**o**		0.2–0.6
1-2	2	**3**									**o**		0.2–0.4
1 (only)	**5**										**u**		0.2 only

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
2-12					2		**3**				**e**		0.4–2.4
2-11					2	1	2					Frequency bands	0.4–2.2
2-10				1	**4**						**ɛ**		0.4–2
2-0				2	2					1			0.4–1.8
2-8			1	**3**						1	**a**		0.4–1.6
2-7				**5**							**a**		0.4–1.4
2-6			**3**	2							**ɔ**		0.4–1.2
2-5		1	**4**								**ɔ**		0.4–1
2-4		**5**									**o**		0.4–0.8
2-3	1	**4**									**o**		0.4–0.6
2 (only)	**4**								1		**u**		0.4 only

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
3-13					**4**		1				**ɛ**		0.6–2.6
3-12					**5**						**ɛ**	Frequency bands	0.6–2.4
3-11					**5**						**ɛ**		0.6–2.2
3-10				1	**4**						**ɛ**		0.6–2
3-9				1	**3**					1	**ɛ**		0.6–1.8
3-8			1	**3**						1	**a**		0.6–1.6
3-7				**5**							**a**		0.6–1.4
3-6			2	**3**							**a**		0.6–1.2
3-5			**5**								**ɔ**		0.6–1
3-4			**5**								**ɔ**		0.6–0.8
3 (only)	**5**										**u**		0.6 only

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
4-14					**5**						**ɛ**		0.8–2.8
4-13					**4**		1				**ɛ**	Frequency bands	0.8–2.6
4-12					**4**		1				**ɛ**		0.8–2.4
4-11					**5**						**ɛ**		0.8–2.2
4-10				2	**3**						**ɛ**		0.8–2
4-9				**3**	1					1	**a**		0.8–1.8
4-8				**5**							**a**		0.8–1.6
4-7				**5**							**a**		0.8–1.4
4-6				**5**							**a**		0.8–1.2
4-5			**5**								**ɔ**		0.8–1
4 (only)	**5**										**u**		0.8 only

Harmonics	Results of the listening test (5 listeners)												Frequency	
Numbers		Confusion matrix										Majority	kHz	
	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	5-15					**4**		1				**ɛ**		1–3
	5-14					**5**						**ɛ**	Frequency bands	1–2.8
	5-13					**5**						**ɛ**		1–2.6
	5-12					**5**						**ɛ**		1–2.4
	5-11					**5**						**ɛ**		1–2.2
	5-10				**3**	2						**a**		1–2
	5-9				**4**						1	**a**		1–1.8
	5-8				**5**							**a**		1–1.6
	5-7				**5**							**a**		1–1.4
	5-6			2	**3**							**a**		1–1.2
	5 (only)	**4**	1									**u**		1 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	6-16					2		**3**				**e**	Frequency bands	1.2–3.2
	6-15					**4**		1				**ɛ**		1.2–3
	6-14					**3**	1	1				**ɛ**		1.2–2.8
	6-13				1	2		2						1.2–2.6
	6-12					**4**		1				**ɛ**		1.2–2.4
	6-11				**3**	1					1	**a**		1.2–2.2
	6-10			1	2	1	1							1.2–2
	6-9			1	**3**		1					**a**		1.2–1.8
	6-8		1		**3**						1	**a**		1.2–1.6
	6-7		1	1	**3**							**a**		1.2–1.4
	6 (only)	2	2								1	**u**		1.2 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	7-17					**3**		2				**ɛ**		1.4–3.4
	7-16					**4**		1				**ɛ**	Frequency bands	1.4–3.2
	7-15					**3**		2				**ɛ**		1.4–3
	7-14				1	**3**		1				**ɛ**		1.4–2.8
	7-13					**4**		1				**ɛ**		1.4–2.6
	7-12				1	**3**		1				**ɛ**		1.4–2.4
	7-11				2	2		1						1.4–2.2
	7-10			1	**3**				1			**a**		1.4–2
	7-9		1		**3**				1			**a**		1.4–1.8
	7-8		1	1	2				1					1.4–1.6
	7 (only)	2									3			1.4 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	8-18					**4**		1				**ɛ**		1.6–3.6
	8-17					**4**		1				**ɛ**	Frequency bands	1.6–3.4
	8-16					**4**		1				**ɛ**		1.6–3.2
	8-15				1	2		2						1.6–3
	8-14					**3**		2				**ɛ**		1.6–2.8
	8-13					**3**		2				**ɛ**		1.6–2.6
	8-12				1	1	1	1			1			1.6–2.4
	8-11				**4**				1			**a**		1.6–2.2
	8-10				**4**				1			**a**		1.6–2
	8-9			1	1	1			2					1.6–1.8
	8 (only)	1			1				2		1			1.6 only

Harmonics	Results of the listening test (5 listeners)												Frequency	
Numbers		Confusion matrix										Majority	kHz	
	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	9-19					**3**		2				**ɛ**		1.8–3.8
	9-18					**3**		2				**ɛ**	Frequency bands	1.8–3.6
	9-17					2		**3**				**e**		1.8–3.4
	9-16					2		2	1					1.8–3.2
	9-15					2	1	2						1.8–3
	9-13					**3**	1	1				**ɛ**		1.8–2.8
	9-13					2	1	1			1			1.8–2.6
	9-12				1	2	1				1			1.8–2.4
	9-11				1		2		2					1.8–2.2
	9-10				1		1		**3**			**y**		1.8–2
	9 (only)								**5**			**y**		1.8 only

Harmonics		Results of the listening test (5 listeners)											Frequency	
Numbers		Confusion matrix										Majority	kHz	
	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	10-20					**3**		2				**ɛ**		2–4
	10-19					**3**		2				**ɛ**	Frequency bands	2–3.8
	10-18					**3**		2				**ɛ**		2–3.6
	10-17					1		**4**				**e**		2–3.4
	10-16					2		**3**				**e**		2–3.2
	10-15					2		**3**				**e**		2–3
	10-14					1	1	1	1		1			2–2.8
	10-13					1	2		1		1			2–2.6
	10-12								**5**			**y**		2–2.4
	10-11				1		1		**3**			**y**		2–2.2
	10 (only)								**3**		2	**y**		2 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	11-20					2		**3**				**e**	Frequency bands	2.2–4
	11-19					**3**		2				**ɛ**		2.2–3.8
	11-18					2		**3**				**e**		2.2–3.6
	11-17							**5**				**e**		2.2–3.4
	11-16					1		**4**				**e**		2.2–3.2
	11-15					1		**3**			1	**e**		2.2–3
	11-14						2	1		1	1			2.2–2.8
	11-13						**3**		1	1		**ø**		2.2–2.6
	11-12					1			**3**		1	**y**		2.2–2.4
	11 (only)								**3**	1	1	**y**		2.2 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	12-20					2		**3**				**e**	Frequency bands	2.4–4
	12-19					1		**3**			1	**e**		2.4–3.8
	12-18							**3**		1	1	**e**		2.4–3.6
	12-17							**4**		1		**e**		2.4–3.4
	12-16							2	1	1	1			2.4–3.2
	12-15						1	**3**		1		**e**		2.4–3
	12-14							1	**3**	1		**y**		2.4–2.8
	12-13								**4**	1		**y**		2.4–2.6
	12 (only)								**3**		2	**y**		2.4 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	13-20							**4**		1		**e**	Frequency bands	2.6–4
	13-19							**4**			1	**e**		2.6–3.8
	13-18							**4**		1		**e**		2.6–3.6
	13-17							**3**		2		**e**		2.6–3.4
	13-16							1		**4**		**i**		2.6–3.2
	13-15							2	2	1				2.6–3
	13-14								**3**	2		**y**		2.6–2.8
	13 (only)								2	2	1			2.6 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	14-20					1		**3**			1	**e**	Frequency bands	2.8–4
	14-19							**4**		1		**e**		2.8–3.8
	14-18							**3**		2		**e**		2.8–3.6
	14-17							2		**3**		**i**		2.8–3.4
	14-16									**5**		**i**		2.8–3.2
	14-15								1	**4**		**i**		2.8–3
	14 (only)								1	**3**	1	**i**		2.8 only

	H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns			
	15-20							**4**		1		e	Frequency bands	3–4
	15-19							2		**3**		i		3–3.8
	15-18							**3**		2		e		3–3.6
	15-17									**5**		i		3–3.4
	15-15							1		**4**		i		3–3.2
	15 (only)								1	**3**	1	i		3 only

Experiment 3: Stepwise increasing harmonics from H(i) (only) to H(i)–H(i+10): Summary.
Red = 5/5 labelling majority; rose = 4/5 labelling majority.

Extension of harmonic series	Frequency in kHz	0.2	0.4	0.6	0.8	1	1.2	14	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8
20	4										ä	e	e	e	e	e
19	3.8									ä	ä	ä	e	e	e	i
18	3.6								ä	ä	ä	e	e	e	e	e
17	3.4							ä	ä	e	e	e	e	e	i	i
16	3.2						e	ä	ä		e	e		i	i	i
15	3					ä	ä	ä			e	e	e		i	i
14	2.8				ä	ä	ä	ä	ä				ü	ü	i	
13	2.6			ä	ä	ä		ä	ä	ä		ö	ü	-		
12	2.4		e	ä	ä	ä	ä	ä			ü	ü	ü			
11	2.2		-	ä	ä	ä	a		a		ü	ü				
10	2	–	ä	ä	ä	a		a	a	ü	ü					
9	1.8	–	–	ä	a	a	a	a		ü						
8	1.6	a	a	a	a	a	a		-							
7	1.4	a	a	a	a	a	a	-								
6	1.2	a	o1	a	a	a	–									
5	1	o1	o1	o1	o1	u*										
4	0.9	o1	o	o1	u*											
3	0.6	o	o	u*												
2	0.4	o	u*													
1	0.2	u*														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Frequency in kHz

First harmonic of a series

Experiment 3: Stepwise increasing harmonics from H(i) (only) to H(i)–H(i+10): Summary (reduced)

Extension of harmonic series	Frequency in kHz	0.2	0.4	0.6	0.8	1	1.2	14	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8
20	4													e		e
19	3.8													e	e	
18	3.6													e		
17	3.4										e	e	e			i
16	3.2							ä				e		i	i	i
15	3					ä	ä								i	
14	2.8				ä	ä										
13	2.6			ä	ä	ä		ä					ü			
12	2.4			ä	ä	ä	ä				ü					
11	2.2			ä	ä	ä			a							
10	2		ä	ä					a							
9	1.8					a				ü						
8	1.6	a			a	a			-							
7	1.4	a	a	a	a	a		-								
6	1.2	a			a											
5	1	o1	o1	o1	o1	u*										
4	0.9		o	o1	u*											
3	0.6		o	u*												
2	0.4		u*													
1	0.2	u*														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Frequency in kHz

First harmonic of a series