**Formant pattern and spectral shape ambiguity in vowel synthesis:
The role of fundamental frequency and formant amplitude**

Materials

Thayabaran Kathiresan[1], Dieter Maurer[2], Heidy Suter[2], Volker Dellwo[1]
[2] Department of Computational Linguistics, University of Zurich, Switzerland
[2] Institute for the Performing Arts and Film, Zurich University of the Arts, Switzerland

Content

1   Listening tests (details)

5 phonetic expert listeners (3 women, 2 men, professionally trained singers or actors) participated in the recognition experiments. For each replication experiment separately, sounds were presented in random order (each sound presented twice). Listeners were asked to assign one of the Standard German vowels /i–y–e–ø–ɛ–a–ɔ–o–u/ or /ə/ (Schwa) or "now vowel recognised". Before a subtest test, the listeners listened to the corresponding sound series in order to get familiar with the synthesised sounds.

Sound recognised as lying in the region of /ɑ–a/ were assigned as /a/. The vowel /ɔ/ was included as an option in the recognition task because the phonetic distance /ɑ–a/–/o/ exceeds the distance of the other neighbouring long Standard German vowels. Schwa was included to allow for the assignment of a sound to be recognised as a central vowel.

In the tests, the listeners were allowed to play back a sound one or multiple times before assigning a vowel quality or a pitch frequency.

2   Results (details)

On the next page, the full results of the listening tests are shown in terms of confusion matrices.

Table (landscape orientation). Column groups: **Original study** — *Sound production: Klatt synthesis parameters (cascade mode)* and *Vowel recognition (previous study)*; **Replication 1: Lowering fo by one octave** — *Vowel recognition (present study)*; **Replication 2: Changing L1'–L2' ratio –10/+10dB** — *Vowel recognition (present study)*; **Replication 3: Changing L1'–L2' ratio –20/+10dB** — *Vowel recognition (present study)*. Confusion-matrix response categories: e1, ɛ, a, ɔ, ø, o, e, y, u, i, B.

Investigation of back vowels

Vowel model	f_o Hz	F_1 Hz	L_1 dB	B_1 Hz	F_2 Hz	L_2 dB	B_2 Hz	F_3 Hz	L_3 dB	B_3 Hz	prev: a	ɔ	o	u	e1	Maj.	R1 f_o Hz	a	ɔ	o	u	i	Maj.	R2 L1'–L2' db	a	ɔ	o	u	i	Maj.	R3 L1'–L2' dbs	a	ɔ	o	u	i	Maj.
o	200	400	100	100	800	105	100	2800	90	200			8	1	1	o	100			10			o	−10/+10		2	8			o	−20/+10	4		6		1	o
u	400	400	100	100	800	105	100	2800	90	200			10			u	200			10			o	−10/+10		4	8	2		o	−20/+10	4		8	2		o
ɔ	200	600	100	100	1200	95	100	3000	85	200	3	7				ɔ	100	6	3	1			a	−10/+10	6	4				a	−20/+10	6		4			a
o	300	600	100	100	1200	95	100	3000	85	200		3	7			o	150	7	3				a	−10/+10		2	8			o	−20/+10	3	2	7			o
u	600	600	100	100	1200	95	100	3000	85	200			10			u	300			10			o	−10/+10	2	3	1	4		–	−20/+10	3	2	5			o

Investigation of front vowels

Vowel model	f_o Hz	F_1 Hz	L_1 dB	B_1 Hz	F_2 Hz	L_2 dB	B_2 Hz	F_3 Hz	L_3 dB	B_3 Hz	prev: e1	ɛ	a	ø	ɔ	o	e	y	u	i	B	Maj.	R1 f_o Hz	ɛ	a	ø	ɔ	o	e	y	u	i	B	Maj.	R2 L1'–L2' db	ɛ	a	ø	ɔ	o	e	y	u	i	B	Maj.	R3 L1'–L2' dbs	ɛ	a	ø	ɔ	o	e	y	u	i	B	Maj.
e	200	400	100	100	2400	100	200	2800	100	200				1		9						e	100					10						e	−10/+10					10						e	−20/+10		1			9						e
i	400	400	100	100	2400	100	200	2800	100	200						1		3		6		i	200					10						e	−10/+10					2		3		5		i	−20/+10				1	1		3		5		i
e	200	400	100	100	2800	100	200	3200	100	200						9			2		1	e	100					10						e	−10/+10					10						e	−20/+10					10						e
i	400	400	100	100	2800	100	200	3200	100	200					8			2			i	200					10						e	−10/+10					10				10		i	−20/+10					2				8		i
ø	200	400	100	100	2000	100	150	2800	100	200				8		2						ø	100			8		4						ø	−10/+10			9		1						ø	−20/+10			8		2						ø
y	400	400	100	100	2000	100	150	2800	100	200								10				y	200					2		9				y	−10/+10							10				y	−20/+10					1		9				y
ɛ	200	600	100	100	2400	100	200	3000	100	200		8									2	ɛ	100	10										ɛ	−10/+10	10										ɛ	−20/+10	10										ɛ
e	300	600	100	100	2400	100	200	3000	100	200		4				6						e	150	10										ɛ	−10/+10		10						10			e	−20/+10		1			9						e
i	600	600	100	100	2400	100	200	3000	100	200								10			5	–	300									10		e	−10/+10					3		1		5		i	−20/+10		1			4			2	4		–
ɛ	200	600	100	100	1800	100	150	3000	100	200	5	5		2								e1-ɛ	100	8										ɛ	−10/+10	2	6			2						ɛ	−20/+10	2	6			2						ɛ
ø	300	600	100	100	1800	100	150	3000	100	200		2		8								ø	150	9		1								ø	−10/+10	2	1	7								ø	−20/+10	1		8				1				ø
y	600	600	100	100	1800	100	150	3000	100	200				2				8				y	300	2										y	−10/+10	4						6				y	−20/+10			5				5				–