Learning Cardinal Vowels

Patricia D.S. Ashby
University of Westminster, London, UK
E-mail: ashbyp@wmin.ac.uk

ABSTRACT

Teaching and learning processes in general phonetic ear-training are often taken for granted and teaching is frequently modelled on techniques established a century ago by phoneticians like Jones, Passy and Viëtor. A recent study of student-responses to Cardinal Vowels, motivated by a wish to facilitate and enhance learning through development of more useful training techniques, revealed interesting and hitherto unknown facts about the perception of Cardinal Vowels from the learner's viewpoint which could impact on materials design for training and assessment purposes. For example, some vowels are more readily perceived/learned than others and one vowel in each adjacent vowels pair seems to be dominant and attract more responses than the other (reminiscent of the perceptual magnet effect described by Kuhl and others in speech perception). Materials produced especially for training purposes need to take these factors into account.

1. INTRODUCTION

Between 1992 and 1997, a longitudinal survey was carried out into aspects of general phonetic ear-training [1], looking specifically at the nature of perceptual judgements made by learners of Cardinal Vowels and the consonants of the International Phonetic Alphabet. This paper concerns selected results relating to Cardinal Vowels. The subjects (Ss) were a heterogeneous group: 125 individuals of diverse age, language background and gender. Ss came from five successive cohorts of first year undergraduate students. None had ever studied phonetics before and Linguistics constituted 50% of their degree.

Focusing principally on responses to the eight primary Cardinal Vowels, it was found that some vowels appear to be more readily identifiable than others with clear differences in perceptibility among these eight values from the learner's point of view. Further investigation revealed that in the majority of cases of adjacent vowel pairs within the primary set (close and close-mid front unrounded, close-mid and open-mid front unrounded, open front and open back unrounded, etc.) one vowel tends to dominate. That is to say, regardless of which member of the pair is presented as a stimulus, one member attracts more responses than the other. There is also an indication that this tendency extends to the perception of secondary Cardinal Vowels.

2. INVESTIGATION

As part of their formal assessment at the end of 12 weeks' training in basic articulatory phonetics (including 12 hours of general phonetic ear-training and 12 hours of phonetic theory, typical of many *ab initio* undergraduate courses in phonetics) Ss were presented with 25 tokens of the primary Cardinal Vowels for identification. These were either in isolation (5 monophthongs and 10 diphthongs) or contextualized in typical nonsense words. They heard each of the ten isolates three times and each of the five nonsense words ten times. The isolates (selected randomly) were [u ɔ ɑ e o ia ɛu ɔi iɑ oe] and the nonsense words [d͡ʒoŋip'], [ɛɬruθ], [çɔɸeŋg], [frɑt͡ʃeɬ], [ɹuɳɗoɳ]. The materials were entirely typical of materials used throughout the training programme. Ss took a further test after 24 weeks of training. In this, all vowels were contextualised in nonsense words and four secondary Cardinal Vowel qualities, [y ø œ ɯ], were also included.

Each response was deconstructed in terms of the traditional openness, backness and rounding parameters employed in vowel description. Use of blatantly English vowel symbols such as [æ] or [ʊ] was disregarded for this purpose and counted as an entirely separate type of error. A safety check for straightforward knowledge of symbols eliminated this as a possible source of errors.

3. PERCEPTION OF INDIVIDUAL VOWELS

Overall results (see Table 1 below) show [i] and [u] being identified correctly across both tests more often than any other single vowel, [i] in 82% of cases (557 times out of 679) and [u] in 85% of cases (529 times out of 625). The next nearest are [ɔ] at 65% and then the open vowel [a] at 64%. These two scores (for [ɔ] and [a]), however, are not significantly different ($p = 0.764$ by chi-squared test). Thus, it is true to say that [i u a ɔ] are the most readily identifiable of the primary Cardinal Vowels.

Effectively, then, we have a situation which may have at least a partial explanation in phonology. Prompted by the universal phonological observation that almost all vowel systems include the basic [i a u] vowel triangle [2], it is perhaps not entirely surprising that these 'extreme points' in the Cardinal Vowel values seem to be more easily identified or learnt by all Ss than other values. Most will be found to

 ISBN 1-876346-48-5

have firsthand real-language experience of vowels of these general types.

Primary Cardinal Vowel	Number of tokens	Number of correct responses	% of correct responses
[i]	679	557	82%
[e]	696	380	55%
[ɛ]	499	248	50%
[a]	283	181	64%
[ɑ]	543	272	50%
[ɔ]	543	353	65%
[o]	648	376	58%
[u]	625	529	85%

Table 1: Overall correct identification of primary Cardinal Vowels

Figure 1 shows these percentage scores in rank order with highly significant differences in rate of success ($p < 0.001$ by chi-squared test).

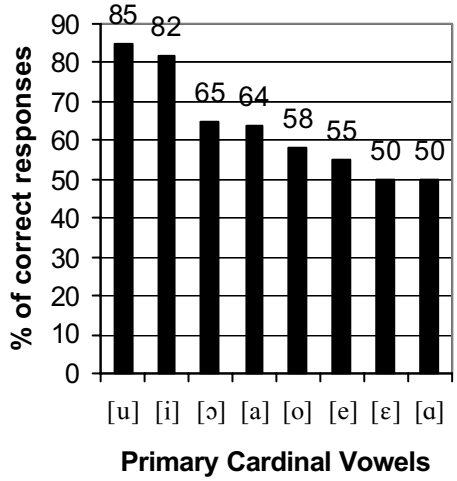

Figure 1 Perceptibility ranking of Primary Cardinal Vowels

The vowels fall into at least three distinct perceptual groups: [i] and [u] form one group, [ɔ] and [a] a second, [o] and [e] a third and [ɑ] and [ɛ] a fourth. Even disregarding the most successfully identified pair ([i] and [u]) the likelihood of the remaining rank order being coincidental is also highly unlikely (again $p < 0.001$ by chi-squared test). Thus it is possible to rank the primary Cardinal Vowels in terms of 'perceptibility', ranging from the most to the least readily identifiable.

4. HEIGHT-ADJACENCY

Speech perception studies (as distinct from the present specialized context of phonetics ear-training) demonstrate difficulties in distinguishing between certain back vowels and between mid-height related pairs (well-known accounts include Fischer-Jørgensen [3] and Ladefoged [4]).

In the present study, height-adjacency was also demonstrated to be a source of difficulty for learners of the Cardinal Vowel system. Height-adjacency is the term coined to refer to all **height-adjacent** pairs: [i/e], [e/ɛ], [ɛ/a], [u/o], [o/ɔ], [ɔ/ɑ], [y/ø], [ø/œ] are all height-adjacent pairs in the present data. The only difference between the two members of each pair is height (except for [ɔ]/[ɑ] where there is also a rounding difference) and in each case, the second member is just one step more open than the first. One further term required to help distinguish errors that fall within the appropriate front/back and primary/secondary ranges, but which do not involve the use of a height-adjacent vowel is **extended height** errors. Extended height errors involve responses of [ɛ] or [a] for [i], [a] for [e], [i] for [ɛ], [i] or [e] for [a], etc.

The misperception of vowel height constituted a substantial proportion of the errors made in vowel identification (see Table 2 below). Of course, there is greater scope for error in judgement of openness compared

	Errors
Backness	20%
Openness	66%
Rounding	14%

Table 2 Percentage of learners' errors of backness, openness and rounding in judgements of Cardinal Vowels

with backness or rounding simply by virtue of the fact that the openness category contains more choices (four vowel heights as opposed to two degrees each of backness and rounding). However, in spite of this possibility, a chi-squared test reveals that the higher frequency of openness errors compared with backness and rounding is highly significant ($p < 0.001$ by chi-squared test).

Taking only the in-range responses (designated "Valid Rs" in figures below and meaning those which fell within the range of Cardinal Vowels actually trained for assessment in a given test - so, in test 1, responses involving secondary Cardinal Vowel symbols, English vowel symbols, etc., are excluded here), it becomes clear from the data presented in Figure 2 below that the errors were almost entirely restricted to the choice of closely related vowels, from the relevant series, that were more often than not height-adjacent. Reading Figure 2, the emboldened numbers on the diagonal represent the number of correct responses while figures in the row immediately above or below show how often height-adjacent vowels were chosen. The figures in these cells are always higher than those in cells further removed along the same column and falling within the shaded areas of the matrix. These more distant, shaded cells represent a mixture of extended height errors and errors simply of backness and/or rounding.

S / R	[i] 500	[e] 500	[ɛ] 250	[a] 125	[ɑ] 375	[ɔ] 375	[o] 500	[u] 500
[i]	**410**	119	1					
[e]	25	**258**	47	3			2	
[ɛ]	6	42	**150**	6	4		1	
[a]		2	13	**71**	67	6		3
[ɑ]			5	15	**195**	6	2	
[ɔ]			1	2	34	**258**	129	6
[o]					8	61	**299**	25
[u]					2	1	10	**425**
Valid Rs:	(441)	(421)	(217)	(91)	(310)	(332)	(440)	(459)

Figure 2 Confusion matrix for in-range responses to primary Cardinal Vowels in test 1

Of the 421 in-range responses logged for [e], for example, 163 are wrong; but of these, a massive 98.8% are choices of the height-adjacent vowels [i] and [ɛ]. This trend continues for [ɛ]: 205 in-range responses are logged, 55 of which are wrong; of the wrong responses, 87.3% are choices of the height-adjacent [e] or [a]. The same pattern is evidenced among the back vowels. For [o], 440 in-range responses are logged of which 141 are wrong; 98.6% of the wrong responses involve the choice of height adjacent [ɔ] or [u]. Likewise for [ɔ], 332 in-range responses are logged of which 74 are wrong; of the wrong responses, 90.5% are choices of the height-adjacent [o] or [ɑ]. (Interestingly, here, choice of the unrounded [ɑ] accounts for only 8.1% of the height-adjacent errors.) There are a few rogue responses in this matrix – inexplicable errors for the most part which would seem to be the product of guesswork rather than a considered decision. In the case of one response of [ɔ] for [ɛ] and two of [e] for [o], the height is (coincidentally?) correct, but the back/front selection is at fault as is the rounding. The extended height errors of [u] and [o] for [ɑ], generating 10 wrong responses altogether, also involve rounding errors which are much less easily understood than the 34 instances of [ɔ] for [ɑ] where jaw aperture influences the lip position of the stimulus such that the lips tend to be more neutral than spread and therefore more readily confused with the open rounding of [ɔ]. Other oddities include 3 instances of [a] for [u] and 1 of [ɛ] for [o].

In summary, of 654 wrong in-range responses in test 1, 517 (79%) were height adjacency errors.

Test 2 data shows a similar relationship between judgements of the backness, openness and rounding categories. Figure 3 and Figure 4 show that 266 or 72% of the 369 responses to the eight primary Cardinal Vowels still involve a straightforward height-adjacent vowel.

S / R	[i] 179	[e] 196	[ɛ] 249	[a] 158	[ɑ] 168	[ɔ] 168	[o] 148	[u] 125
[i]	**147**	20	1					
[e]	8	**122**	75	2				
[ɛ]	2	15	**98**	7	2	1		
[a]		2	20	**110**	40	1		
[ɑ]		1	5	19	**77**	6	1	
[ɔ]					4	**95**	47	1
[o]						48	**77**	10
[u]							6	**104**
Valid Rs:	(157)	(160)	(199)	(138)	(123)	(151)	(131)	(115)

Figure 3 Confusion matrix for in-range responses to primary Cardinal Vowels in test 2 involving primary Cardinal Vowel values

S / R	[i] 179	[e] 196	[ɛ] 249	[a] 158	[ɑ] 168	[ɔ] 168	[o] 148	[u] 500
[y]	2	1					1	2
[ø]		1			2	1	1	
[œ]				1	5		1	
[ɯ]	1	1	2					3
Valid Rs:	(3)	(3)	(2)	(1)	(7)	(1)	(3)	(5)

Figure 4 Confusion matrix for in-range responses to primary Cardinal Vowels in test 2 involving secondary Cardinal Vowel values

However, Figure 4 shows that with the inclusion of members of the secondary series, the number of rogue responses increases. The picture becomes more complicated still when results for the secondary Cardinal

S / R	[y] 125	[ø] 125	[œ] 60	[ɯ] 125
[y]	**32**	4	1	3
[ø]	1	**27**	6	3
[œ]		18	**20**	3
[ɯ]	3	1	1	**40**
[i]				6
[e]		6	2	4
[ɛ]		3	9	2
[a]			1	
[ɑ]				1
[ɔ]		4	2	1
[o]	3		2	1
[u]	65	21		15
Valid Rs:	(104)	(84)	(44)	(79)

Figure 5 Confusion matrix for in-range responses to primary Cardinal Vowels in test 1

ISBN 1-876346-48-5

vowel stimuli themselves are studied. Overall, there is still a preponderance of height-adjacent responses (295 or 53% of the total 561 wrong in-range responses) but Figure 5 shows very clearly that height-adjacency is only a small part of the identification problem for the secondary Cardinal Vowels themselves.

Compared with the 72% of errors of judgement concerning primary Cardinal Vowels involving height-adjacency, among responses to the secondary Cardinal Vowels, a mere 15% fall into this category. Confusions of backness and rounding are also far more commonplace here.

5. DOMINANT AND DOMINATED VOWELS

Cell entries in Figures 2, 3 and 5 above suggest that the relationship between certain adjacent pairs of vowels (not only height-adjacent, but also the 'adjacent' open vowels [a]/[ɑ]) may not be an entirely equal one. Some vowels, it seems, contribute more to interference or misperception (called here **dominant** vowels) than others (called here **dominated** vowels).

Adjacent pairs	**Number of correct responses**	**Wrong responses**	
		First vowel identified as second	*Second vowel identified as first*
[i]/[e]	[i] = 82% [e] =54.6%	2.4%	10.1% [i] dominant
[e]/[ɛ]	[e] =54.6% [ɛ] =49.7%	4.8%	10.2% [e] dominant
[ɛ]/[a]	[ɛ] = 49.7% [a] = 64%	4.2% [a] dominant	1.7%
[a]/[ɑ]	[a] = 64% [ɑ] = 50.1%	4.1%	13% [a] dominant
[ɑ]/[ɔ]	[ɑ] = 50.1% [ɔ] = 65%	3.5% [ɔ] dominant	1.1%
[ɔ]/[o]	[ɔ] = 65% [o] = 58%	8.9%	14.8% [ɔ] dominant
[o]/[u]	[o] = 58% [u] = 85%	1.3%	2.7% [o] dominant
[y]/[ø]	[y] = 25.6% [ø] = 21.6%	0.4%	1.6% [y] dominant
[ø]/[œ]	[ø] = 21.6% [œ] = 33.3%	9.7% [œ] dominant	3.2%

Table 3 Summary of relationships between adjacent pairs of in-range primary and secondary Cardinal Vowels

These relationships are summarised in Table 3 where it can be seen that for each adjacent pair there is one value that attracts the greatest number of responses: it is more often identified correctly and of all the responses to the vowel pair in question, it features most frequently among the wrong height-adjacent responses. One vowel in each adjacent pair appears to have some kind of perceptual dominance, calling to mind the perceptual magnet effect described by Kuhl and Iverson [5] for speech perception studies. The only pair for which this is not apparent is [u]/[o]. ([u] is identified correctly more often, but [o] features more often in wrong responses affecting this pair of vowels.)

In the primary series, it can be seen, for example, from the results in Table 5 that close-mid front [e] and open [a] both tend to dominate at the expense of open-mid [ɛ]. Similar interference is seen among the back vowels with [ɔ] dominating at the expense of both [ɑ] and [o]. Moreover, [ɑ] also appears to be dominated by the adjacent front [a], making this a particularly problematic quality for learners.

6. CONCLUSIONS

In conclusion, it is fair to say that the above findings are all of interest on two accounts. Firstly, they serve to inform the trainers regarding practical difficulties that are likely to be encountered by *ab initio* students of phonetics with the Cardinal Vowel system. In the wider field, however, they raise more theoretical issues of a perceptual nature including questions regarding the nature of the model internalised by the learner and its relation to that learners active real-language phonologies.

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