SPEECH AND LANGUAGE THERAPY (SLT) STUDENTS' PRODUCTION AND PERCEPTION OF CARDINAL VOWELS: A LONGITUDINAL CASE STUDY OF SIX SPEECH AND LANGUAGE THERAPY STUDENTS

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Abstract
This paper investigates six English-speaking speech and language therapy students producing and perceiving cardinal vowels around the time of their final practical phonetics examination and seven months after the examination. The study identified certain cardinal vowels as difficult in both production and perception. The participants' confidence ratings reflected their performance well overall, but they appeared to be overly confident about their ability to produce close and open vowels and under confident about their ability to perceive close-mid and open-mid vowels. The participants retained the relevant skills over the seven-month period, but one participant performed much worse in the second testing session, suggesting that there may be significant variation between individual students.

1. Introduction

Speech and language therapy (SLT) students studying for a qualifying BSc or MScdegree in the UK take one or more classes in practical phonetics, which involve learning to produce and perceive unfamiliar sounds. As far as learning vowel sounds is concerned, they are usually expected to learn to recognise and produce at least cardinal vowels 1–11, 13 and 16 (primary cardinal vowels 1–8 and secondary cardinal vowels 1–3, 5 and 8). Practising speech and language therapists (SLTs) need to be able to transcribe vowel qualities appropriately when they work with clients with problems with vowel articulation (see e.g. Howard & Heselwood, 2002; Local, 1983), and the accurate transcription of vowels is also important for establishing the interactions between consonants and vowels in syllable production in atypical speech (Ball, 1991; Bates, Watson & Scobbie, 2002). It is therefore important that SLT students attain the phonetic ability necessary for using the cardinal vowel framework accurately and effectively in their work.

This study looks at six English-speaking SLT students' ability to produce and perceive all cardinal vowels in tests carried out three to eight days before the students' final practical phonetics examination in March 2009 and then again seven months later. It aims to shed light on the most common problems experienced by the SLT students in producing and perceiving these vowels, whether they experience problems with the same vowels in the production and perception tests and, if so, whether the same features cause problems in both production and perception. Furthermore, it looks at how well the students retain the relevant phonetic ability over a seven-month period after completing their practical phonetics training. The question of whether the students perform better on sounds they claim to feel more confident about in comparison with sounds they report feeling less confident about is also investigated. The rest of this section reviews some of the previous research that is relevant to this study.

With there being a relative lack of published research into learner factors that mayinfluence SLT students' acquisition of unfamiliar sounds, one must turn to studies dealing with problems faced by second language (L2) learners in learning to perceive

and produce new vowel qualities as these are likely to be shared by SLT students learning such sounds. The fact that L2 learners tend to perceive the sounds of their target language in terms of the sounds of their first language (L1) is well attested in the literature: Trubetzkoy (1969: 52) describes L1 as "a sieve through which everything that is said passes". Wells (2000) notes that L2 speakers tend to use sounds and sound patterns familiar from their L1 when speaking an L2. A number of theoretical models which seek to account for L2 speech learning have been devised. For example, Flege's (1987, 1991, 1992) speech learning model suggests that learning to produce sounds that are only marginally different from L1 sounds can often be more problematic than sounds which are very different from any of those in the learner's native phonological inventory. It is to be noted that there are approaches which suggest that L2 sounds which involve phonetic dimensions with which the learners have little previous experience are easier to learn than sounds which differ more from the learner's L1 sounds (see e.g. Escudero 2005), which contradicts with the predictions of Flege's (1987, 1991, 1992) speech learning model. Kuhl's native language magnet model (e.g. Grieser and Kuhl 1989; Iverson and Kuhl 1995, 1996, 2000) suggests that L1 speakers have prototypes for L1 categories such as vowels which result in the surrounding perceptual space being shrunk. This model allows for predictions to be made regarding the perceptibility of L2 contrasts, e.g. distinguishing between two unfamiliar sounds which are mapped onto the same L1 prototype is more difficult than distinguishing between L2 sounds which are mapped onto different L2 prototypes. Best's (1993, 1994, 1995) perceptual assimilation model proposes that L2 learners perceive L2 segments either as categorised, i.e., mapped onto a single L1 category, uncategorised, i.e., mapped onto more than one L1 category or non-assimilable, i.e., not mapped onto any L1 category. Her model also allows for predictions to be made regarding the perceptibility of particular L2 contrasts. For example, two L2 segments may be mapped onto different L1 categories, in which case distinguishing between the sounds in question will be easy, or two L2 segments may be mapped onto the same L1 category, and in this case distinguishing between the two L2 sounds will be difficult. Best (1995) also suggests that there may be L2 contrasts whose acquisition is neither aided or hindered by L1 phonology for L2 learners such as when neither L2 segment is mapped onto any L1 category. Based on the aforementioned models and studies it can be expected that SLT students are likely to perceive new sounds in terms of their L1 phonological inventory, and SLT students who speak different languages and accents are likely to face different kinds of difficulties in learning unfamiliar sounds.

There is a large number of studies that suggest that increased age is correlated with less sophisticated language learning ability (e.g. Munro, Flege & MacKay 1996; Patkowski 1990; Piske, MacKay & Flege 2001; Scovel 1969, 1988). Munro, Flege & MacKay's (1996) study looked at L2 vowel acquisition specifically and concluded that there is a steady decline in performance corresponding to the age at which a person starts acquiring a second language that continues until the late teens. However, it should be noted here that these studies look at the acquisition/learning of vowel phonemes in context (i.e. in words), whereas here we examine the articulation of cardinal vowels in isolation; one must therefore be cautious in placing too much reliance on comparisons of this sort.

Linguistic background and age are by no means the only factors that may influencea learner's phonological attainment in a second language. Language learning aptitude (Suter, 1976; Thompson, 1991), gender (Asher & Garcia, 1969; Tahta, Wood

& Loewenthal, 1981), motivation (Elliott, 1995; Purcell & Suter, 1980; Suter, 1976) and talent (Jilka 2009a, 2009b) may also influence a learner's ultimate attainment, which varies greatly between learners. Moyer (2004) brings together some of the work that has been done in this area and critically examines the assertion that ultimate attainment in second language learning is dependent mainly on age. The different learner factors that have been shown to be influential in second language learning mentioned above are likely to apply to SLT students learning to produce and perceive new speech sounds. However, only first language background is systematically addressed in this study.

Whitworth (2008a) asserts that the success of individual SLT students on a practical phonetics module appears to be dependent on their perception of particular sounds as either hard or easy. Whitworth (2008a, 2008b) conducted two separate questionnaire-based surveys into SLT students' perception of sounds, one in 2007 targeting SLT students at the beginning of their second year of study, and another in 2008 targeting students in the first term of the first year of study at Leeds Metropolitan University, UK. Whitworth's (2008a, 2008b) studies focussed on which sounds the SLT students found most difficult to produce and perceive and whether there was a difference between sounds perceived as difficult to produce as opposed to sounds perceived as difficult to perceive (it should be noted that the participants were not taught [œ], [ʌ] and [ɤ]). In terms of production, both participant groups rated [ɯ] as the most difficult cardinal vowel, followed by [ø] and [œ] (Whitworth, 2008b). While the two groups agreed on the three most difficult cardinal vowels, the 2008 group found [e] more difficult to produce than [ɔ], [o] and [y], which the 2007 group found more difficult than [e] (Whitworth, 2008b). This would suggest that while there is generally a consensus amongst students regarding which cardinal vowels are most difficult, slight variation is to be expected between cohorts of students, individual students, and possibly between students studying at different levels, i.e., between first year students vs. second year students. In terms of transcription, the 2007 group reported [o] as most difficult, followed by cardinals [ɔ], [ø], [œ] and [y] and [ɯ] (Whitworth, 2008b). The 2008 group, by contrast, reported [ø] as being most difficult, followed by [œ], [o], [ɔ], [e] and [ɛ]. As with production, SLT students appear to find perceiving some vowels more difficult than others, but it is also interesting to note that [e] and [ɛ] were rated as more difficult in relation to the other cardinal vowels by the 2008 group (Whitworth, 2008b), which tie in well with their reported lack of confidence in being able to produce [e] discussed above. Whitworth (2008a, 2008b) did not investigate the correlation between SLT students' confidence ratings and their actual performance. The present study investigates both performance and confidence ratings and is thus relevant to the important question of the reliability of students' self-assessment of problems experienced in practical phonetics.

There is to the authors' knowledge no published research regarding English-speaking SLT students' ability to produce and perceive cardinal vowels. However, Knight (2009, 2010) investigated SLT students' perception of the relationship between their accuracy in phonetic transcription and the number of repetitions and new voices. Knight (2009, 2010) found that SLT students generally felt that their transcriptions were more accurate when they head stimuli several times and that they were not confident about transcribing new voices. Ashby (2002, 2003) has studied the effectiveness of general phonetic ear-training in helping first year undergraduate linguistics students learn to perceive cardinal vowels. Ashby (2002, 2003) carried out a longitudinal survey of 125 undergraduate students of different ages and language

backgrounds, including both male and female students, between 1992 and 1997. The aim of the survey was to shed light on the perceptibility of cardinal vowels. With regards to the primary cardinal vowels, she found that the participants were most successful in perceiving [i] and [u], followed by three distinct perceptual groups of varying difficulty (with the first mentioned group being least difficult and the last mentioned group most difficult): [a] and [ɔ]; [e] and [o]; and [ɛ] and [ɑ] (Ashby, 2002, 2003). Ashby's data thus suggest that some vowel qualities tend to be selected at the expense of others (Ashby, 2002, 2003). She also found that vowel height was the most difficult feature as far as the primary cardinal vowels are concerned with 72% of errors being vowel height errors (Ashby, 2002, 2003). However, the corresponding figure for secondary cardinal vowels was only 15%, i.e., backness and roundedness were more problematic with regards to secondary cardinal vowels (Ashby, 2002, 2003).

Ashby's findings concerning students' performance on primary cardinal vowelsagrees well with studies on speech perception (e.g. Fischer-Jørgensen, 1985; Ladefoged, 1967) that suggest that distinguishing between vowels that differ in vowel height can be very difficult. Ashby's (2002, 2003) participants were not tested on [œ], [ɒ] and [ʌ], and her participants reflect a range of language backgrounds, so there is scope for further investigation into how English-speaking students in particular perceive cardinal vowels and for the inclusion of [œ], [ɒ] and [ʌ]. It is also important to investigate whether the patterns identified by Ashby (2002, 2003) with respect to dominant sounds, i.e. sounds which are selected over other sounds in the same region of the auditory-acoustic phonetic space, are applicable to production as well as perception. This study considers these issues. Crookston (1999) investigated whether SLTs' phonetic transcription skills progress, remain static or degenerate after graduation. One important element of phonetic training for SLT students at most UK institutions is teaching them how to transcribe a well-known accent of English (usually RP or near-RP) phonemically (Crookston, 1999). Some of the participants had graduated approximately 3.5 years previously while others had graduated approximately 2.5 years before (Crookston, 1999). The study required respondents to transcribe six words written orthographically as they would be pronounced by an RP speaker or a speaker of any educated South-Eastern England accent; these were then compared with the transcriptions they supplied in their last formal assessment in phonemic transcription which consisted of a dictation task. Crookston's (1999) study showed that, overall, the practicing SLTs performed almost exactly as well in the post-graduation questionnaire as in their final student assessment. The findings suggest that SLT students generally retain their knowledge of IPA chart symbols, or at least the IPA chart symbols needed to transcribe RP or RP-style English, well after graduation.

Based on the discussion in the preceding sections, the following research questionsare posed in this study:

1. What are the most common problems in producing and recognising cardinal vowels among SLT students who have completed a practical phonetics module and do the participants have problems with the same sounds and the same features of sounds in both production and perception?
2. Do they perform better on vowels they feel more confident about in comparison with sounds they claim to feel less confident about?
3. How well do the participants retain the relevant phonetic knowledge over a seven-month period after their final practical examination?

2. Method

2.1 Participants

Students enrolled in the practical phonetics class 'Clinical Phonetics and Phonology' at the University of Reading, UK, in the academic year of 2008/2009, were asked to take part in this study. The students take this class during the second year of their BSc degree in SLT or in their first year of the MSc degree in SLT. The practical work on the students' clinical phonetics module, which involves the students being taught how to produce and transcribe most IPA chart sounds, including all cardinal vowels, during one hour sessions, includes five preparatory classes, not all of them practical, in the summer term in their first academic year for the BSc students followed by 10 practical classes in the spring term in their second year, while the MSc students receive six hours of practical instruction in the autumn term and 10 hours of further instruction in the spring term in the same year. For the BSc sessions, the class is split into two small groups of around 15 students, both taught by the same lecturer, whereas the MSc group (usually between 10–15 students in any one year) is taught by a different lecturer. Both lecturers are phonetically trained native speakers of English. In addition to the requirement that participants be students on SLT degree programmes at Reading, two further requirements were imposed. The first was that the participants should be monolingual speakers of RP or near-RP English. For the purposes of this study, a speaker of RP or near-RP was defined as someone who speaks with a British English accent that does not incorporate any very noticeable regional features (cf. Wells, 1982: 279–301; Windsor Lewis, 1972: xiv) as reported by the participants. This requirement was imposed because, as is apparent from the survey of models of L2 speech learning in the Introduction, SLT student learners are likely to map cardinal vowels onto L1 vowels differently according to their L1 vowel system. Thus speakers of different English accents and languages are likely to encounter different kinds of difficulties in learning cardinal vowels so that taking the speakers' linguistic background into account seems relevant. In particular, this enables easy and systematic analysis of errors according to relevant models of L2 speech learning which in turn may help identify more general trends where difficulties in acquiring cardinal vowels is concerned. The second requirement was that the participants should not have received any phonetic training prior to commencing their SLT degree at the University of Reading. This requirement was imposed because cardinal vowels would not be new sounds to someone who has received relevant phonetic training previously. Six eligible female students came forward and were recruited to the study. No age-related requirements were imposed as it was judged unlikely that age would be a factor of great significance in a higher education setting where virtually all students are adults; as pointed out in the introduction, previous research on L2 learners suggests that the ability to learn new vowel sounds declines until one's late teens. Of the six participants in the study, three were in the age bracket 18–24, one was in the age bracket 25–35 and two were in the age bracket 36–45.

2.2 Data collection and analysis

The six participants (numbered 1 to 6) attended two individual testing sessions: onethree to eight days before their practical phonetics examination in March 2009, and another in October of the same year. Each testing session began with the participant completing a questionnaire in which they were asked to rate their perceived confidence with regards to their ability to produce and identify cardinal vowels 1–16 on an attitude scale of 1–4, where 4 refers to 'very confident' and 1 to

‘not at all confident’. We found this rating task to be easy for participants to understand and very useful for obtaining data that can relatively easily be compared with other data, such as the performance scores in the production and perception tests. The participants were not specifically instructed to use the entire scale in order to allow for the participants to report that they perceived all cardinal vowels as equally difficult should they wish to do so.

The production test was conducted as follows. The participants were asked to produce cardinal vowels 1–16 in numerical order, pausing between each vowel. They were allowed to look at the 2005 version of the chart of the International Phonetic Alphabet (IPA, 2005) while carrying out this task. The task was completed in a sound-treated room at the University of Reading and the participants’ productions were recorded to enable further analysis. The data were recorded onto a Dell Precision 670 computer using an AKG d80 microphone. The data were sampled at the rate of 44.1 *KHz* with the signal being quantised at 16 bit. The recordings were saved as WAV-files.

Two options were considered for establishing how close to target the participants’productions. One option was that of analysing the recordings by ear only. This method was judged too subjective for the purposes of the present study, and the participants’ vowels were instead analysed acoustically and compared with those of their lecturers, numbered 7 and 8. Acoustic analysis of the data was practicable as the number of tokens generated was relatively small.

PRAAT speech analysis software (Boersma & Weenink, 2007) was used foranalysing the speech data initially. *PRAAT*’s LPC formant tracker was used for locating F1 and F2. A window of 25 ms was used, and the formant values were read off the display and recorded onto Microsoft Excel spreadsheets. The midpoint of each vowel was used for measurement unless there appeared to be a glide in the production on the basis of auditory analysis of the tokens, in which case the start and end points of the vocalic segment were measured to establish the nature of the glide. The Lobanov (1971) vowel normalisation method was used for eliminating the effects of anatomical differences on the formant data. The NORM package (Kendall, Tyler & Thomas, 2009) was used for Lobanov-normalisation and for plotting the participants’ and lecturers’ formants graphically, the normalisation formula being $F_{n[V]}^{N} = (F_{n[V]} - MEAN_n)/S_n$. Here $F_{n[V]}^{N}$ stands for the normalised value for $F_{n[V]}$ for formant *n* of vowel *V*, $MEAN_n$ is the mean value for formant *n* for the speaker in question and S_n is the standard deviation for the speaker's formant *n* (Thomas & Kendall 2007).

Although methods for establishing roundedness by acoustic means have beensuggested (see e.g. Ladefoged, 2003:131–133; Stevens, 1998:290–294), these were judged too impractical for the purposes of the present investigation. Instead, the degree of lip-rounding was established by the first author by observing the participants when the data were elicited.

In the perception test, the participants were told they were going to hear the eight primary and eight secondary cardinal vowels, and only these vowels, as they occur in an audio-recording, and that each vowel would be played three times. They were instructed to supply the appropriate International Phonetic Alphabet symbol for each vowel sound played. For this test, the participants were not allowed to look at the IPA chart. The sound files used were those available through the clickable IPA chart on the CD accompanying Ladefoged’s *A course in phonetics* (2006). This standard recording was chosen to ensure the fairness of the test in the light of the fact that different lecturers had taught the BSc and MSc groups. Before the test started, a

central vowel between close-mid and open-mid was played, and the participants asked to confirm that the volume was acceptable. The cardinal vowels 1–16 were then played in a randomised order. Three repetitions was judged sufficient to allow for the participants to check their transcriptions as they only transcribed one segment at a time; Ashby (2002) judged three repetitions to be sufficient for isolates.

The participants' performance in the two testing sessions was scored to allow foreasy comparison between the individual participants' performances in the first and second testing sessions and between the participants' collective performance on the different vowel sounds. The scoring of the performances was carried out as follows. The participants' productions of cardinal vowels were compared with those of the lecturers by looking at the normalised vowel plots (see Appendix 1) and establishing whether each production was close enough to that of the lecturers in terms of backness and vowel height. The first author rated the rounding at the time of vowel eliciation. A mark between 0 and 3 was awarded for each production in the production tests and for each entry in the perception tests with one mark being given for accuracy with regards to each of three features: backness, vowel height and roundedness. This method was chosen on the basis that it was judged objective. A full mark was given if a production was judged to be perfectly acceptable with respect to a feature, i.e., close to either lecturer's production as shown on the relevant normalised vowel plot or rounded/unrounded as appropriate, or, in the case of the perception test, the participant's entry was correct with respect to the feature in question. Half a mark was given if a production appeared to be almost, but not quite, correct as far as a particular feature is concerned, particularly where the relevant midpoint measurement was approximately halfway between either lecturer's cardinal vowel and closer to that than any other cardinal vowel (half marks were not used in marking the perception tests, and it is acknowledged that there is greater scope for error with regards to vowel height considering that this category contains more choices than backness or rounding). A mark of zero was given if the production was demonstrably incorrect, e.g., when the plotting revealed that a feature of a target cardinal vowel was produced in a way that is associated with another cardinal vowel, or, in the case of the perception test, the participant supplied a symbol that showed that the participant had not identified a relevant feature accurately, e.g., giving the symbol for a rounded vowel when the target was unrounded.

After the scoring was done, an average score was calculated for each participant's individual performance in all the production and perception tests. An average score was also calculated for the participants' collective performance on each vowel sound.

3. Results

Figures 1 to 12 show the participants' Lobanov-normalised formant values compared to those of the lecturers. Table 1 shows the participants' production test scores and the distribution of marks on the scale of 0–3 in the first production tests based on a comparison of the participants' productions with those of the lecturers, as described in the method section, and the participants' confidence ratings on the scale of 1–4 as reported in that testing session.

As the relevant Figures show, the distinction between [e] and [ɛ] was quiteproblematic, particularly in the first production tests with no participant producing [e] perfectly correctly; most participants produced a more open vowel similar to [ɛ]. Cardinal [a] was also difficult in these tests with the participants tending to produce vowels which were too close or too far back. Cardinal [o] was often

confused with [ɔ] and [u]. The participants were relatively good at producing [ø] with two participants attracting full marks and two participants attracting 2.5 marks out of 3 while [y], [œ] and [ɶ] caused more problems; with respect to [œ], as comparison of the relevant Figures and the scores reported in Table 1 reveals, it was the rounding that caused most problems with half the participants producing unrounded vowels, while backness and vowel height were the more problematic features regarding [ɶ]. The back cardinal vowels [ɤ] and [ɯ] were both very difficult; four participants produced open-mid back vowels for [ɤ] while the rounding and backness were more difficult with regards to [ɯ] with three participants producing unrounded vowels and two participants producing front vowels. Comparison of the participants' confidence ratings and production test scores reported in Table 1 reveals the participants seemed to feel overly confident about their ability to produce [e] and [a] while reporting less confidence with regards to producing [ø] and [ɶ] than was reflected in their performance while their confidence ratings and production test scores seem to match each other fairly well for the other cardinal vowels.

Figure 1. Participant 1's and the lecturers' formant values for primary cardinal vowels Lobanov normalised

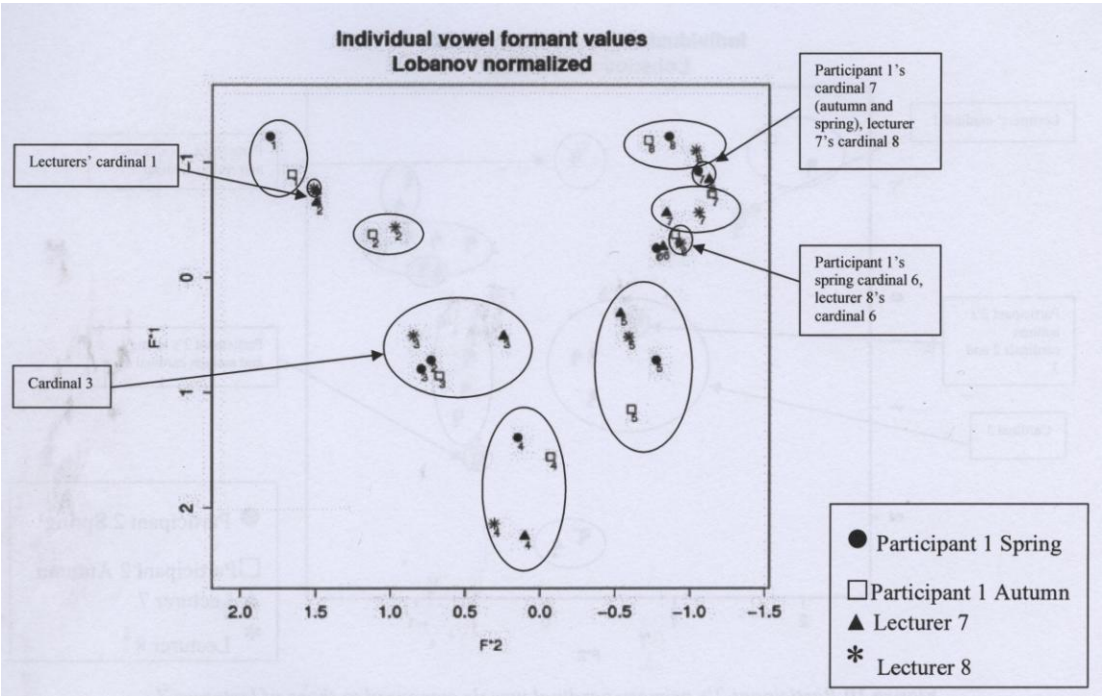


Figure 2. Participant 1's and the lecturers' formant values for secondary cardinal vowels Lobanov normalised

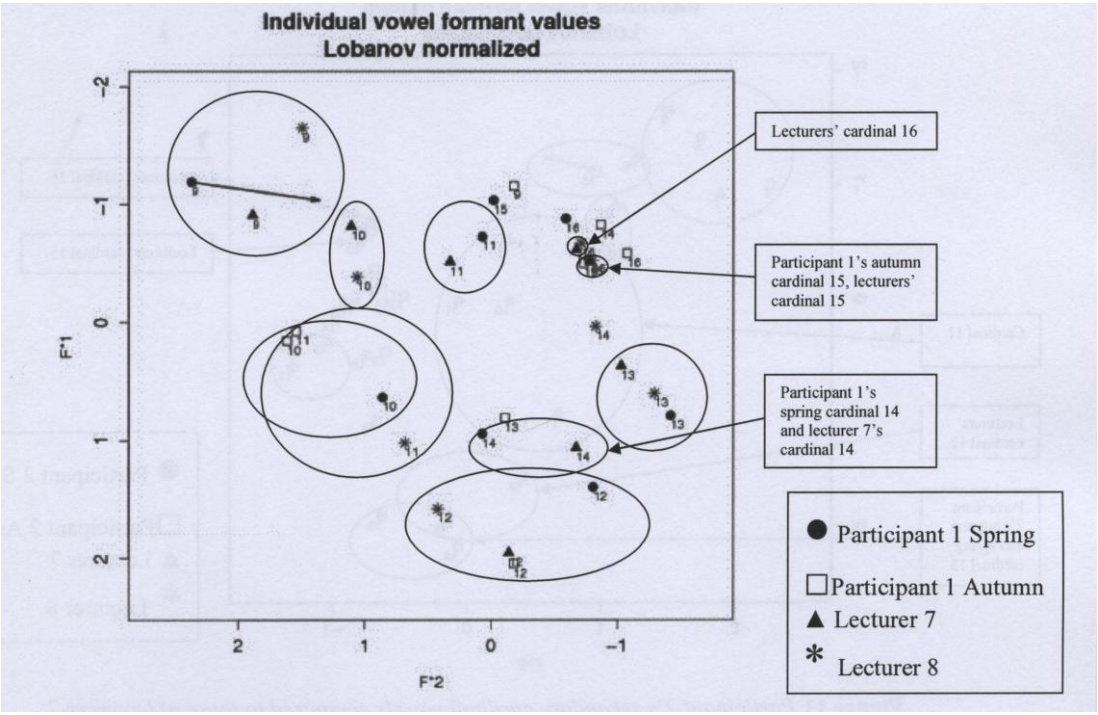


Figure 3. Participant 2's and the lecturers' formant value for primary cardinal vowels Lobanov normalised

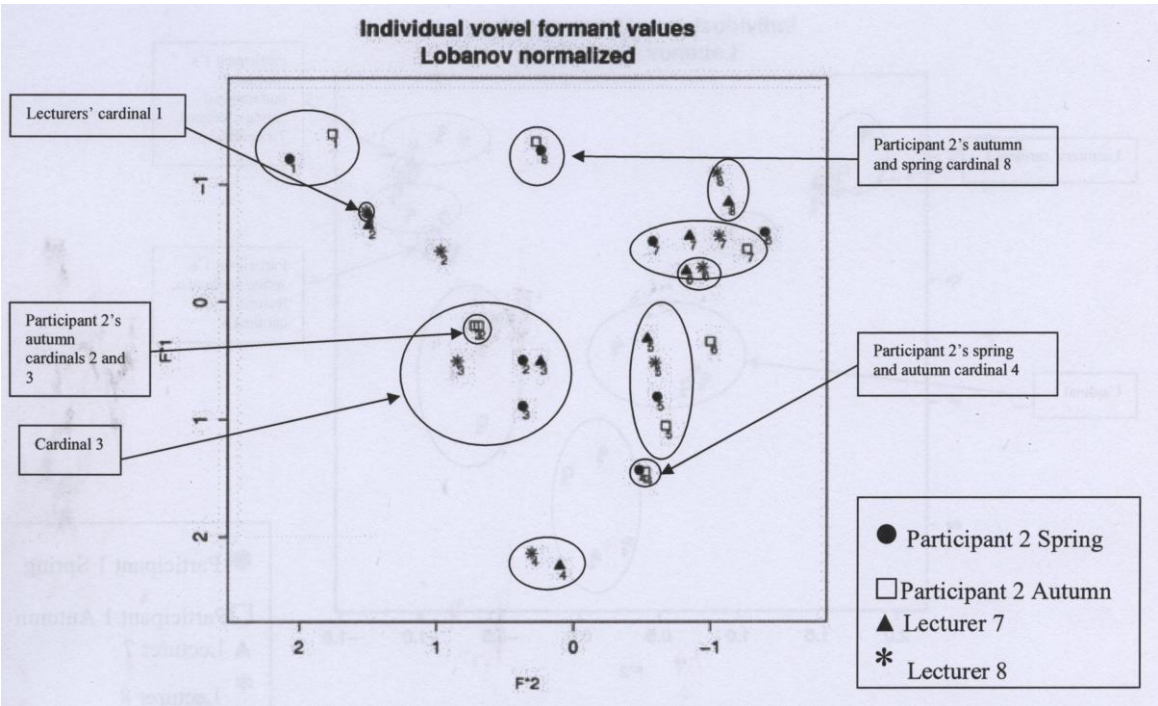


Figure 4. Participant 2's and the lecturers' formant values for secondary cardinal vowels Lobanov normalised

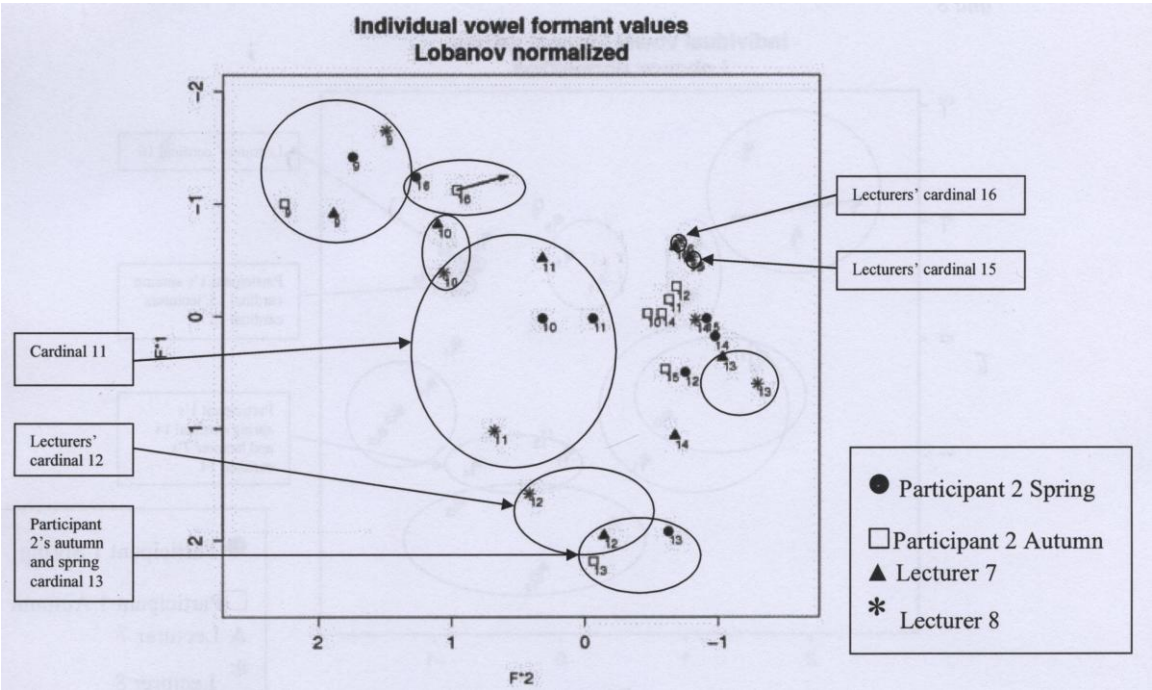


Figure 5. Participant 3's and the lecturers' formant values for primary cardinal vowels Lobanov normalised.

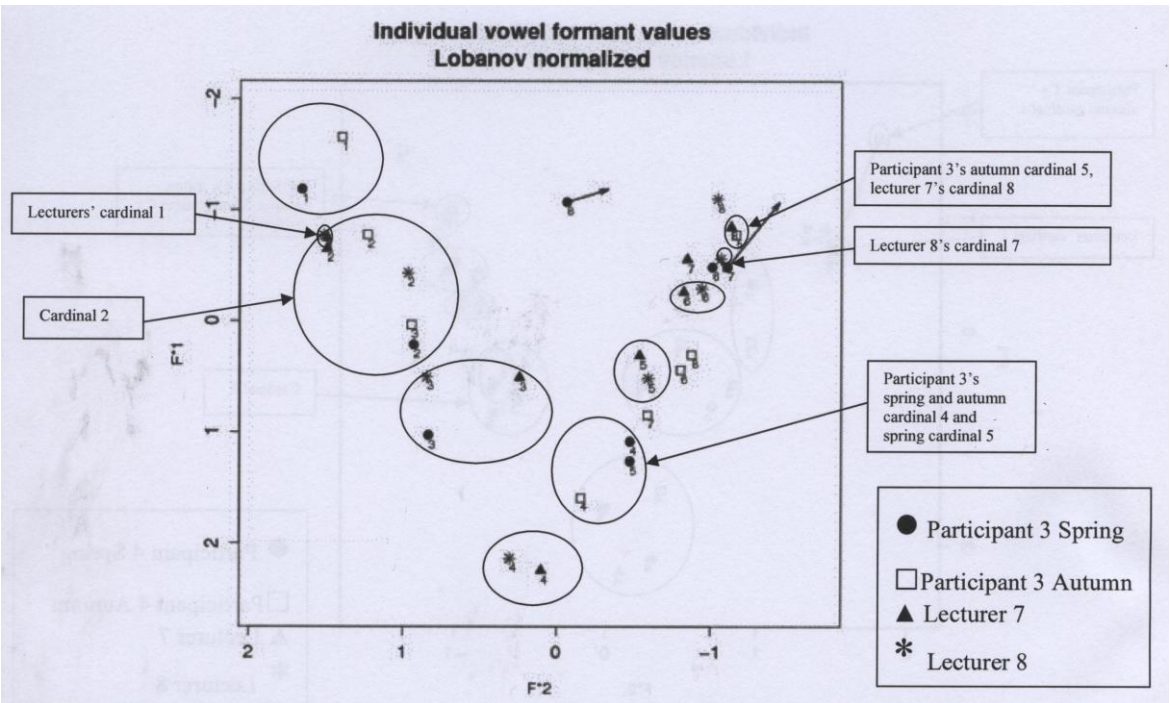


Figure 6. Participant 3's and the lecturers' formant values for secondary cardinal vowels Lobanov normalised.

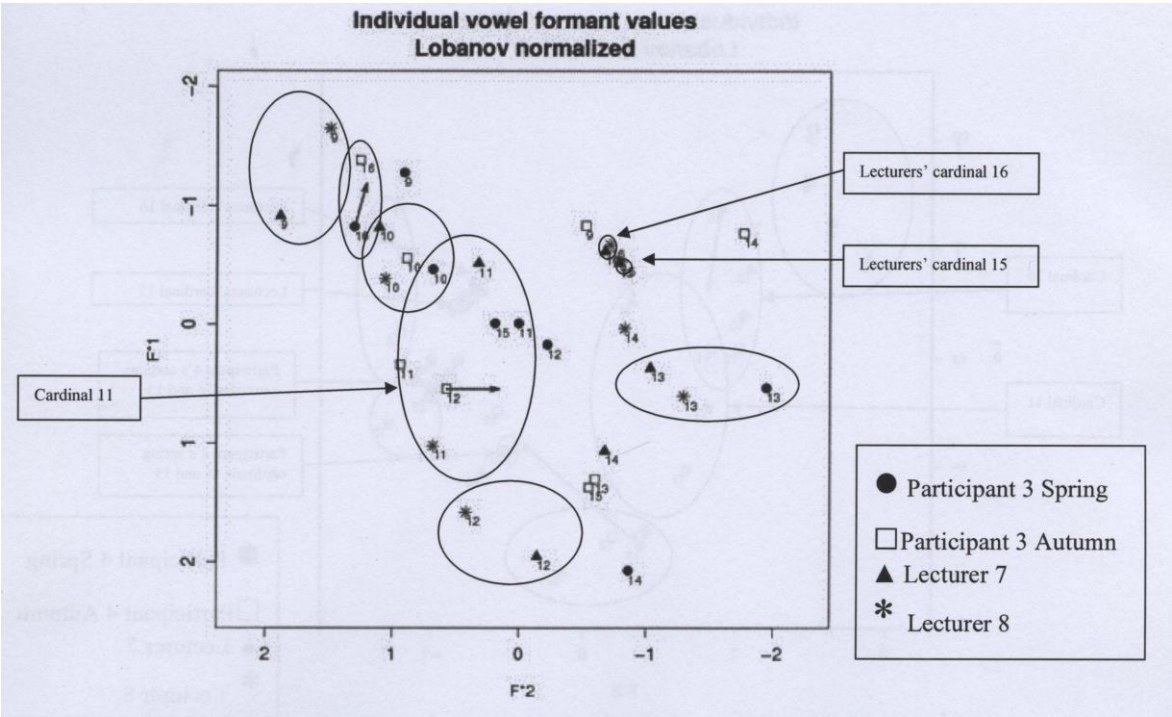


Figure 7. Participant 4's and the lecturers' formant values for primary cardinal vowels Lobanov normalised

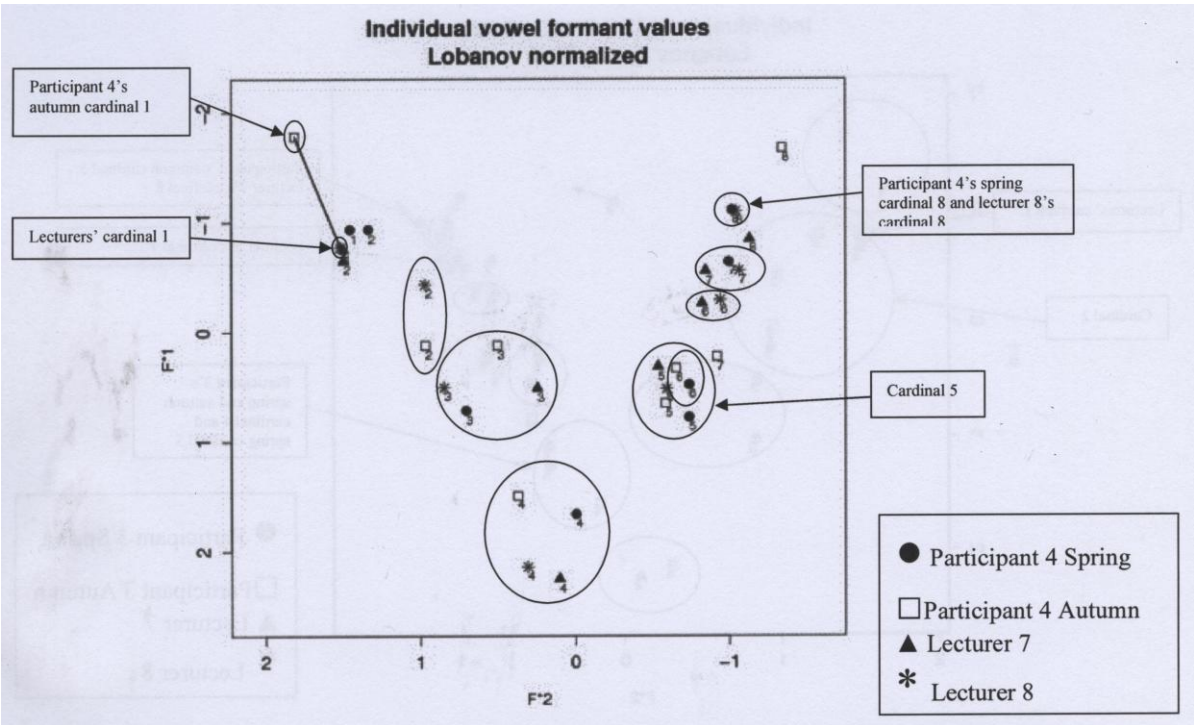


Figure 8. Participant 4's and the lecturers' formant values for secondary cardinal vowels Lobanov normalised

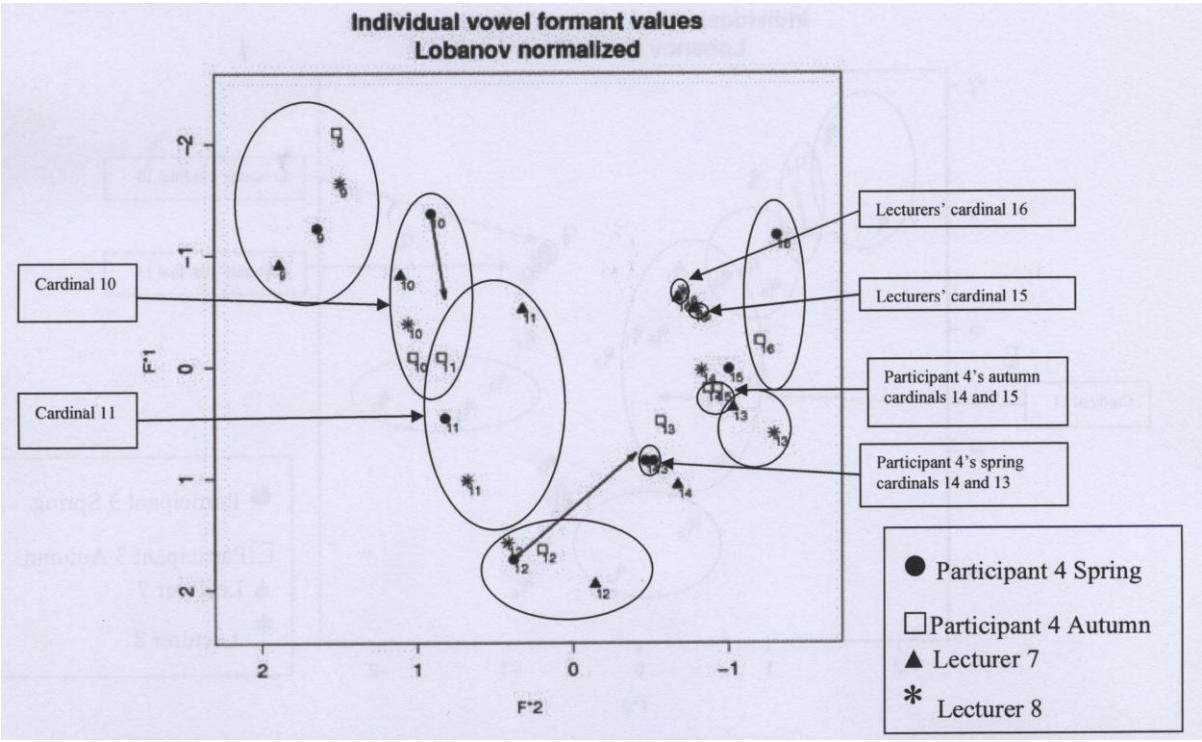


Figure 9. Participant 5's and the lecturers' formant values for primary cardinal vowels Lobanov normalised

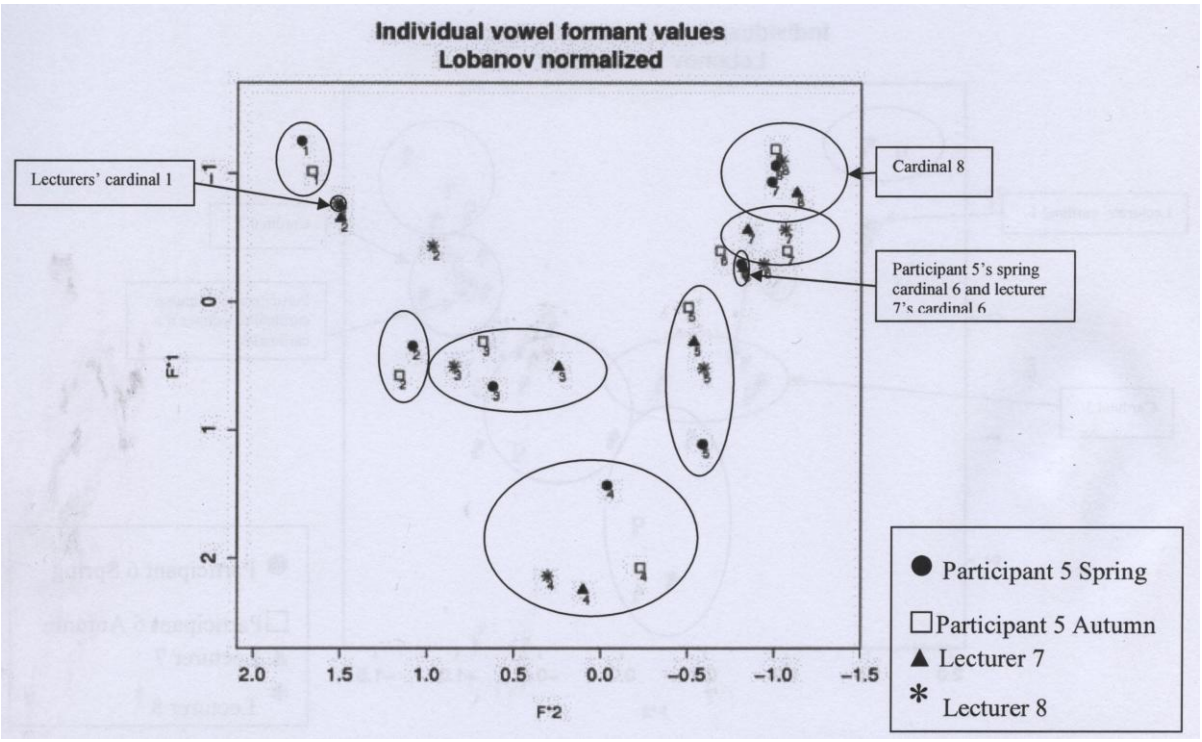


Figure 10. Participant 5's and the lecturers' formant values for secondary cardinal vowels Lobanov normalised

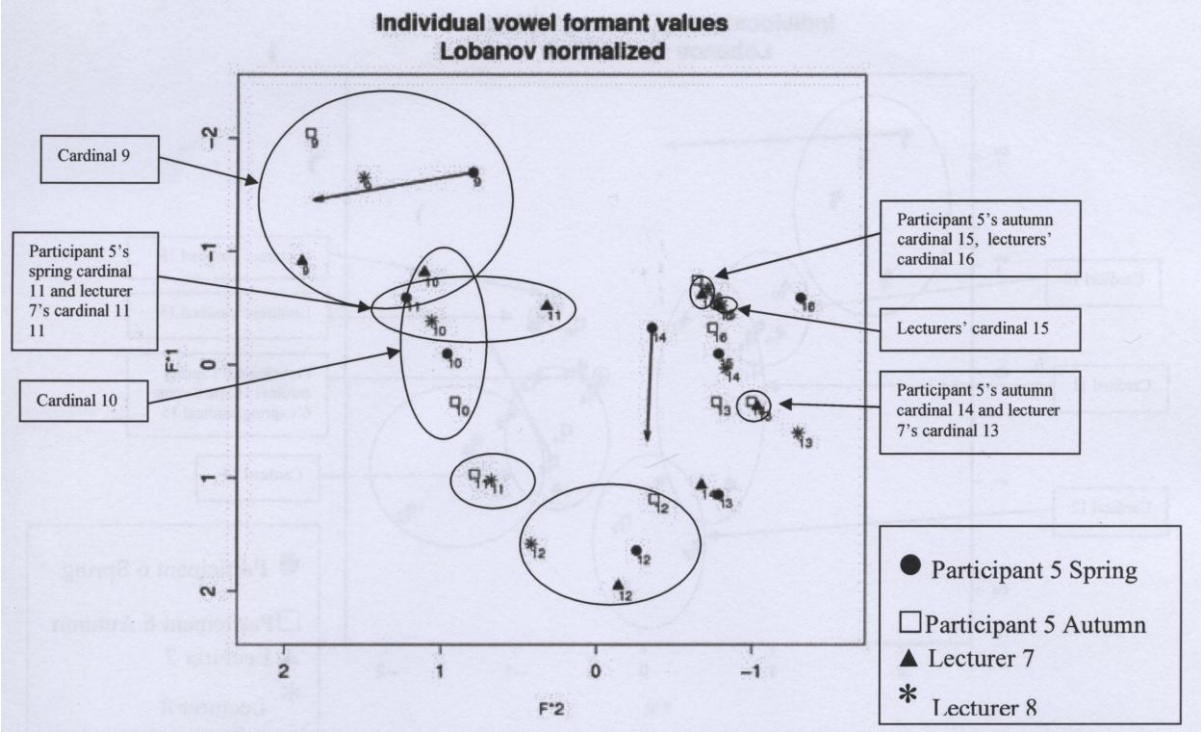


Figure 11. Participant 6's and the lecturers' formant values for primary cardinal vowels Lobanov normalised

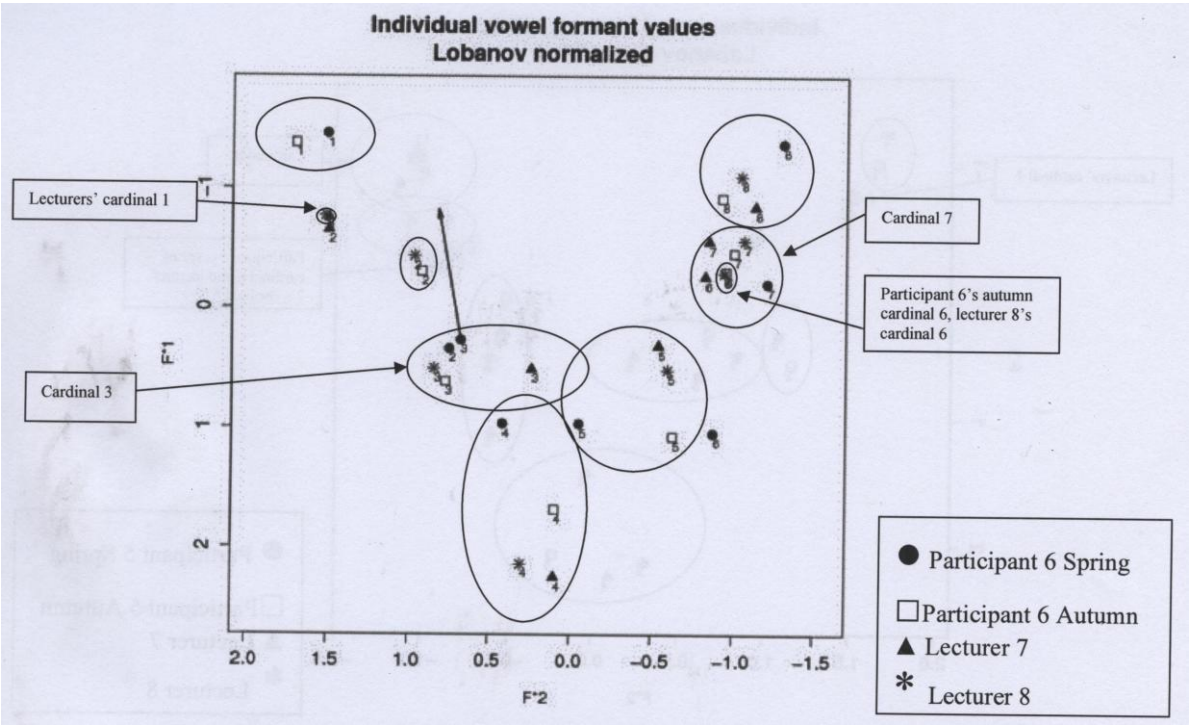
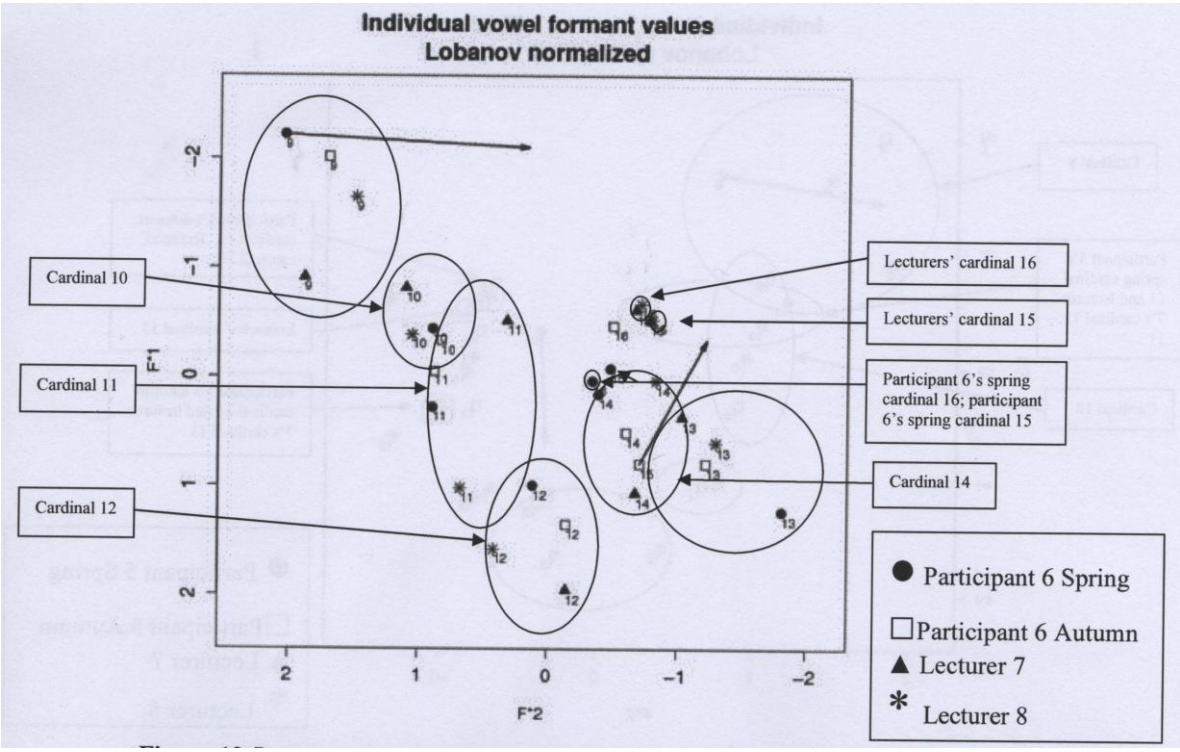


Figure 12. Participant 6's and the lecturers' formant values for primary cardinal vowels Lobanov normalised



Having described the participants' performance in the first production tests above,we turn now to comparing the participants' performances in the spring and autumn tests. Table 2 shows the participants' individual scores for their two production tests. The participants generally did very well producing cardinal vowels in both tests,performing within the range of 71–82% in the first test and 59–82% in the second test. As the difference in the standard deviation (4.1 in the first test vs. 10.3 in the second) makes clear, there was much more variation between the participants' scores in the second test.

Figure 13 compares the collective production test scores calculated by adding all the participants' marks, dividing the sum with 18 (the maximum number of marks available for the participants) and multiplying by 100 for the different sounds in the first and second tests. The participants' collective production test score was 5–9 percentage points higher for cardinals 4, 5 and 15; 10 or more percentage points higher for [e] ; 5–9 percentage points lower for [o] and [ø] and 10 or more percentage points lower for cardinals [u], [y], [ɒ] and [ʌ] in the second production test.

The participants faced very similar problems in both of the testing sessions. The main differences which need to be pointed out are that two participants managed to produce [e] perfectly correctly in their second testing session which no participant did in their first test, and that the participants tended to experience more difficulty with rounding in the second testing sessions, with three participants producing a rounded vowel for [ʌ], two participants producing an unrounded vowel for [ɒ] and one participant getting the rounding wrong for half the vowels.

Table 1. Results in the first production test and participants' perceived confidence as reported in that testing session

Vowel	Production Test Score (%)	Distribution of marks on the scale 0 – 3 (number of participants awarded a particular mark in brackets)	Perceived confidence as reported by the participants
i	100	3 (6)	4 (6)
e	67	2 (6)	3 (2), 2 (4)
ɛ	97	3 (5), 2.5 (1)	4 (1), 3 (2), 2 (3)
a	75	2.5 (4), 2 (1), 1.5 (1)	4 (2), 3 (2), 2 (2)
ɑ	92	3 (5), 1.5 (1)	3 (3), 2 (3)
ɔ	75	3 (2), 2 (3), 1.5 (1)	3 (1), 2 (4), 1 (1)
o	78	3 (2), 2 (4)	3 (2), 2 (2), 1 (2)
u	86	3 (3), 2.5 (1), 2 (2)	4 (2), 3 (3), 1 (1)
y	78	3 (2), 2.5 (1), 2 (2), 1.5 (1)	3 (3), 2 (2), 1 (1)
ø	81	3 (2), 2.5 (2), 2 (1), 1.5 (1)	2 (3), 1 (3)
œ	69	3 (1), 2.5 (1), 2 (3), 1 (1)	3 (1), 2 (2), 1 (3)
ɶ	58	2.5 (2), 2 (1), 1.5 (1), 1 (2)	2 (3), 1 (3)
ɒ	78	3 (3), 2.5 (1), 1.5 (1), 1 (1)	2 (3), 1 (3)
ʌ	72	2.5 (3), 2 (2), 1.5 (1)	3 (1), 2 (3), 1 (2)
ɤ	42	2 (1), 1.5 (3), 1 (1), 0 (1)	2 (1), 1 (5)
ɯ	58	3 (1), 2 (3), 1 (1), 0.5 (1)	3 (3), 2 (1), 1 (2)

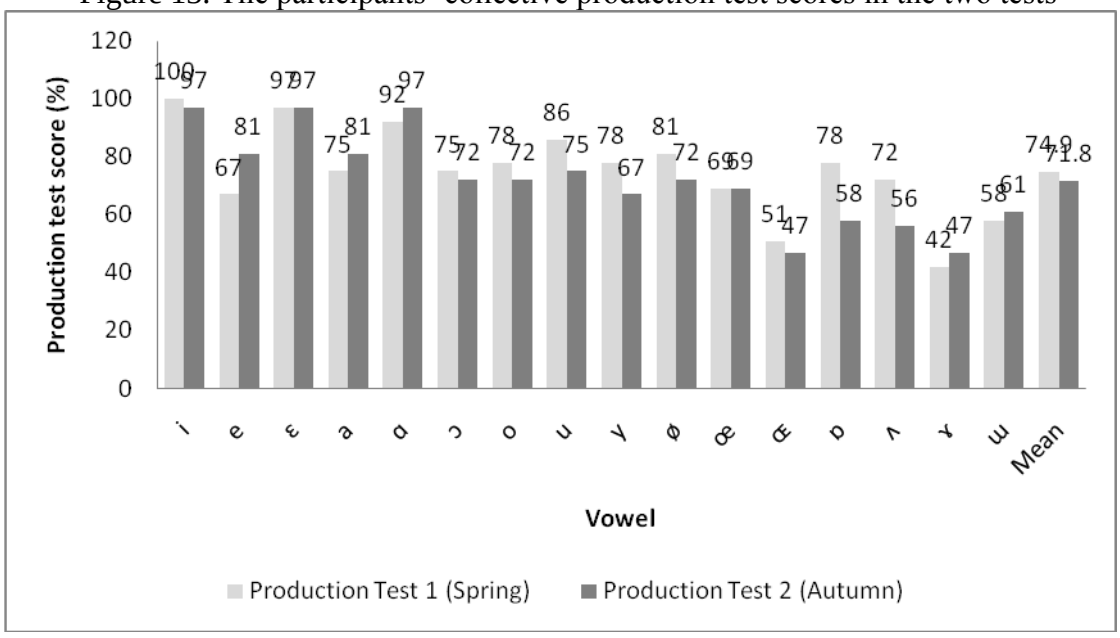
Table 3 shows the participants' perception test scores, the phonetic symbol supplied by the participants and the participants' confidence ratings on the scale of 1–4 as reported in that testing session. The table indicates that the participants were good at judging [i], [e] and [ɛ]. As can be seen from this table, [a] was frequently confused with [ɑ] and no participant identified [ɑ] correctly in the first perception test even though they did well on this vowel in the production test; they tended to perceive it is a back rounded vowel. Cardinal [ɔ] was confused with [o] by two participants and one participant did not supply any phonetic symbol for this sound and only one participant identified [o] correctly in their first testing session; the participants tended to confuse it with other back vowels, but this was not limited to the rounded [ɔ] and [u] as in production. Two participants confused [u] with the unrounded [ɯ] and two participants confused it with [y] in their first testing session while the most common problem in production was to produce a too fronted vowel. Cardinal [y] was perceived by half the participants as a back vowel. Three participants identified [ø] correctly

while two confused it with another front rounded vowel and one participant confused it with a back unrounded vowel. Cardinal [œ] was identified correctly by two participants and confused with [ɶ] by one participant while three participants did not supply any symbol for this sound. Cardinal [ɶ] was frequently misidentified as an unrounded or back vowel. The back [ɒ], [ʌ], [ɤ] and [ɯ] all proved to be very difficult to identify; some participants failed to categorise some of these sounds in any way in the test, leaving the space for supplying the appropriate phonetic symbol blank.

Table 2. The participants' overall scores in the production tests.

Participant	Test 1 (Spring) Score (%)	Test 2 (Autumn) Score (%)
1	**78**	**81**
2	**72**	**60**
3	**71**	**59**
4	**75**	**71**
5	**82**	**78**
6	**74**	**82**
Mean	**75.3**	**71.8**
Median	**74.5**	**74.5**
Standard deviation	**4.1**	**10.3**

Figure 13. The participants' collective production test scores in the two tests



As far as the participants' confidence ratings are concerned, comparison between the confidence scores and perception test scores provided in Table 3 indicates that the participants were overly confident about their ability to perceive [ɒ] and [ɯ] while getting [ɛ], [ɔ] and [ø] right more often than one might expect based on their self-reported sense of confidence. The confidence ratings seem to match the participants' performance relatively well for the other cardinal vowels.

Table 3. Results in the first perception test and participants' perceived confidence as reported in that testing session

Vowel	Collective Perception Test Score (%)	Symbols supplied where appropriate, zero refers to a participant not supplying any symbol for the relevant stimulus (number of participants in brackets, correctly identified tokens indicated by tick)	Perceived confidence as reported by the participants
i	100	i√ (6)	4 (6)
e	78	e√ (4), y (1), ɤ (1)	4 (1), 3 (2), 2 (3)
ɛ	94	ɛ√ (5), e (1)	4 (1), 3 (4), 2 (1)
a	78	a√ (2), ɑ (4)	4 (2), 3 (2), 2 (1), 1 (1)
ɑ	50	ɔ (2), ɒ (3), o (1)	4 (1), 3 (1), 2 (3), 1 (1)
ɔ	72	ɔ√ (3), o (2), zero (1)	3 (2), 2 (3), 1 (1)
o	67	o√ (1), ʌ (1), ɤ (1), ø (1), ɔ (1), u (1)	3 (2), 2 (3), 1 (1)
u	78	u√ (2), y (2), ɯ (2)	4 (3), 3 (3)
y	61	y√ (1), u (3), ɯ (2)	3 (2), 2 (3), 1 (1)
ø	72	ø√ (3), y (1), œ (1), ʌ (1)	3 (1), 2 (3), 1 (2)
œ	44	œ√ (2), zero (3), ɶ (1)	2 (4), 1 (2)
ɶ	28	œ√ (1), ɜ (1), e (1), ø (1), ʌ (1), ɯ (1)	2 (2), 1 (4)
ɒ	39	œ (2), ɶ (1), ɔ (1), ʌ (1), zero (1)	3 (1), 2 (4), 1 (1)
ʌ	50	ʌ√ (1), ɤ (2), o (1), ɒ (1), zero (1)	2 (4), 1 (2)
ɤ	39	ɤ√ (1), o (1), ɔ (1), ɒ (1), zero (2)	2 (1), 1 (5)
ɯ	44	ɯ√ (1), ɤ (2), y (1), zero (2)	4 (2), 3 (1), 2 (2), 1 (1)

Table 4 gives the participants' individual scores in their two perception tests. If one compares Table 4 with Table 2, it is clear that the participants' performance in the first perception tests was worse than their performance in the first production tests, with the range of marks being 58–65% expressed in the participants' overall scores (cf. 71–82% in production); the standard deviation was relatively similar in the first production and perception tests (4.1 in the former vs. 3.4 in the latter). As Table 4 shows, the participants generally performed better in their second perception test

compared with the first, with only one participant performing worse in her second testing session. Participant 2, who performed worse, was let down by the fact that the phonetic symbols she gave for two of the sounds in the test were unclear; she also performed worse in the second production test. This contrasts with performance in the production tests where four participants performed worse in their second testing session.

Figure 14, which compares the participants' collective perception test scores, shows that the score was 10 or more percentage points higher for cardinals [ɔ], [o], [u], [y], [œ], [ɒ], [ʌ] and [ɯ], 5–9 percentage points lower for [ɛ], and 10 or more percentage points lower for [ɑ], [ø] and [ɤ] in the second perception test. In the first testing sessions the participants did better on cardinals [ɑ], [o], [u], [y] and [ɒ] in the production test than in the perception test. In the second testing sessions, by contrast, this was only true for [ɑ]; the participants were much more successful in identifying cardinals [o], [u], [y] and [ɒ] than in producing them.

Figure 14. The participants' collective perception test scores in the two tests

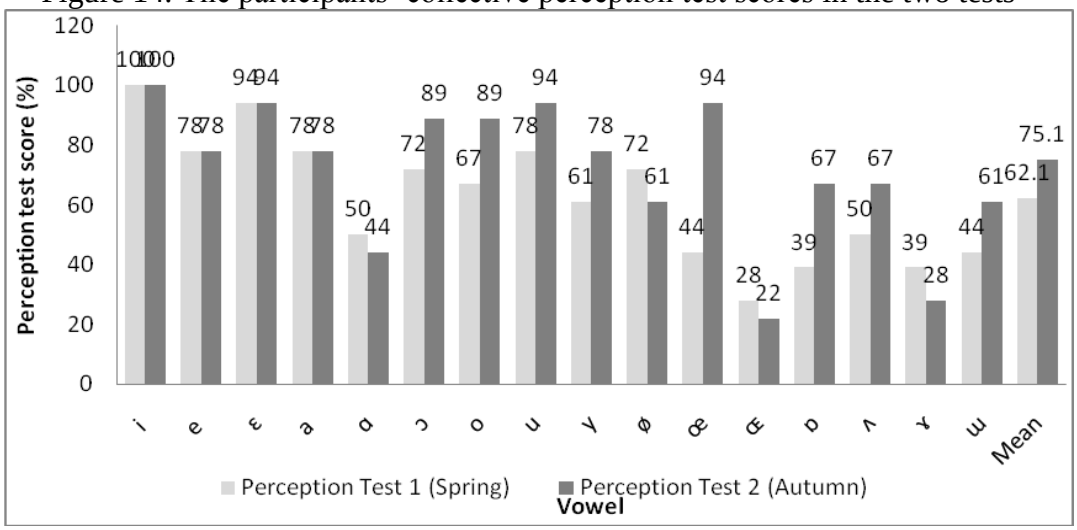


Table 4. The participants' individual scores in the two perception tests

Participant	Test 1 (Spring) Score (%)	Test 2 (Autumn) Score (%)
1	**58**	**65**
2	**63**	**54**
3	**58**	**75**
4	**65**	**77**
5	**65**	**81**
6	**65**	**73**
Mean	**62.3**	**70.8**
Median	**64.0**	**74.0**
Standard deviation	**3.4**	**9.8**

4. Discussion and implications

The analysis presented in the previous section revealed that the distinction between [e] and [ɛ] was quite problematic in the production tests with no participant producing [e] completely accurately in their first testing session and only two participants producing it correctly in their second testing session; most participants produced a more open vowel similar to [ɛ]. The fact that the participants tended to produce an open-mid vowel more similar to the default realisation of the phoneme /e/ and the onset of phoneme /eɪ/ in their accent (Cruttenden, 2008; Roach, 2004) when targeting close-mid [e] corresponds with the predictions of Flege's (1987, 1991, 1992) speech learning model that it is learning to produce sounds that are only marginally different from L1 sounds that is particularly problematic. This would seem to contradict Escudero's (2005) finding that it is dealing with phonetic dimensions with which the learners have little experience that is most difficult as L1 RP speakers have a complex vowel system. However, considering the finding that the participants also faced problems with producing [a] and [o] the problem with producing [e] could potentially be due simply to a lack of sufficient exposure to cardinal vowels.

Cardinal [a] was difficult with the participants tending to produce too close vowel or vowels too far back. Cardinal [ɔ] caused a number of problems and [o] was often confused with [ɔ]. This is somewhat surprising considering that RP /æ/ is now almost identical to cardinal [a] and /ɔː/ is typically similar to cardinal [o] (e.g. Cruttenden, 2008) and models of L2 speech learning would therefore predict that these sounds should be particularly easy to learn (e.g. Best, 1995; Flege, 1987, 1991, 1992). The problems with these vowels could be taken to suggest that the participants do not have a secure enough grasp of these cardinal vowel categories to enable them to produce these vowels correctly. More exposure to the relevant cardinal vowels would probably be important to remedy this problem. Cardinals [y], [œ], [ɶ], [ɤ] and [ɯ] were also problematic in production. The fact that [e], [œ], [ɶ] and [ɤ] caused problems while the participants were more successful at producing [ɛ], [ø] and [ʌ] shows that Ashby's (2002, 2003) conclusion that vowel height is the feature that tends to cause most problems in vowel perception does also hold true for vowel production, with certain sounds tending to dominate over others in that dimension. For example, the participants were more likely to produce a cardinal [ʌ] -like sound than a cardinal-[ɤ] -like sound, regardless if the target was [ʌ] or [ɤ]. In teaching students who are speakers of RP-style English to produce cardinal vowels, a great deal of time may need to be devoted to distinguishing between cardinal vowels differing in vowel height in practical phonetics teaching if students are to become proficient in these distinctions. The fact that front rounded vowels and back unrounded vowels were generally difficult, which in the case of [y] involved problems with backness and roundedness, suggests that learning new vowels of a kind not present in the learners L1 system is generally difficult which agrees with Escudero's (2005) finding. Since this study has identified that SLT students learning cardinal vowels face problems both with sounds that are relatively similar to L1 sounds and sounds that are more different from L1 sounds the findings of this research show that it is necessary to place emphasis on training such learners well on all relevant cardinal vowels and underscore the point that sufficient category training and exposure to cardinal vowels is crucial for them to learn to produce cardinal vowels well.

With regards to the perceptibility of the cardinal vowels, it can be said that, in general, the participants were very good at recognising the different cardinal vowels in the spring and autumn perception tests. Some problems did however emerge which

warrant further discussion. Surprisingly, no participant identified [ɑ] correctly in any of the perception tests. Considering this, it appears likely that the participants' perception of the proximity of cardinal 5 to RP /ɑː/ is faulty in that the chief variant of RP /ɑː/ is not as back as cardinal 5 (Cruttenden, 2008:117–118; Roach, 2004) which means that the participants do not perceive /ɑː/ as an [ɑ]-type sound and instead judge it to be a back rounded vowel on the basis of its phonetic properties. Cardinals [ɔ], [o] and [u] caused problems for many participants in their first testing session, but the participants' performance on these sounds was much better in the second sessions. This might be because the participants were less concentrated in their first testing session, possibly because the fact that they were due to sit their practical phonetics examination soon caused additional stress whereas the second testing sessions were conducted outside the examination period. Alternatively, these results could reflect improvements on these vowels. The participants in the present study were so successful in identifying primary cardinal vowels with the exception of [ɑ] that no reliable patterns of the kind identified by Ashby (2002, 2003) regarding certain sounds tending to dominate over others in the vowel height dimension can be identified. It is however important to point out that Ashby (2002, 2003), as opposed to the present study, also tested her participants' ability to identify cardinal vowels in context, which is likely to be more difficult than recognising them in isolation. This study does not therefore furnish strong evidence against Ashby's (2002, 2003) hypothesis but rather suggests that students can learn to recognise primary cardinal vowels reliably in isolation providing they are given sufficient training.

Cardinal [y] was quite difficult in the perception tests, with most participants perceiving it as a back vowel, though there were slightly fewer problems with this sound in the second tests. The confusability between [y] and [u] is well-established in the literature (see e.g. Flege 1987; Mayr & Escudero 2010) and this finding serves as a reminder that this distinction requires prolonged attention for native RP speakers. The participants commonly perceived [œ] as a different vowel or failed to categorise it in the first test and [ɶ] as unrounded or back vowels in their first test, but demonstrated a more secure grasp of [œ] in the second test. The back cardinal vowels [ɒ], [ʌ], [ɤ] and [ɯ] were very difficult in the first test with [ʌ] and [ɤ] being particularly problematic in both tests; vowel height was the most problematic feature for these vowels followed by roundedness. The findings with regards to [ɒ], [ʌ], [ɤ] and [ɯ] suggest that vowel height is the most problematic feature in the perception of these vowels which contradicts with Ashby's (2002, 2003) findings, which indicate that backness and roundedness are the most problematic features where the secondary cardinal vowels are concerned, and agree with Fischer-Jørgensen's (1985) and Ladefoged's (1967) claim that the vowel height dimension is most problematic in speech perception. It might be suggested that Ashby's (2002, 2003) limited inclusion of secondary cardinal vowels in her study may have had an impact on her results.

As the preceding discussion shows, it may be necessary to place particularly strong emphasis on the quality of [ɑ], [y], [ɶ], [ɤ] and [ɯ] in ear training where a majority of the students are speakers of RP-style English to ensure that students are able to distinguish these reliably. As is true for the findings concerning production, this study suggests that SLT students learning cardinal vowels face problems both with sounds that are relatively similar to L1 sounds and sounds that are more different from L1 sounds. The amount of ear training required is likely to be substantial especially in the light of Iverson & Evans's (2009) finding that short-term auditory training does not result in the formation of new target-language categories in L2 speech learning.

As far as the relationship between performance in perception and production is concerned, it was found that [e], [a], [o], [œ], [ɶ], [ɤ] and [ɯ] were most difficult to produce while [ɑ], [y], [ɶ], [ʌ] and [ɤ] caused most problems in the perception tests. For [a], the most problematic feature was different in production and perception; the backness of this sound tended to cause more problems in perception whereas its openness was more problematic in the production tests. This study suggests that lecturers teaching practical phonetics need to be aware of the fact that students may face more problems with certain sounds, especially front vowels, in production relative to perception and perhaps spend more time training the students in producing these vowels. Furthermore, as was mentioned in the Results section, the participants in this study performed better in the production than in the perception test. This is surprising considering that studies of L2 speech learning tend to show that learners speech perception abilities exceed their performance in production (e.g. Borrell, 1990; Neufeld, 1988). This finding could be explained by the fact that the participants find it hard to identify cardinal vowels when produced by an unfamiliar voice, in this case Ladefoged rather than the lecturer who taught them cardinal vowels while being able to produce such vowels more accurately on the basis of their model.

With respect to the second research question, this study adds to Whitworth's (2008a, 2008b) previous work in the area in that it examines the links between the students' confidence ratings and empirical data on their performance thus furnishing useful evidence concerning students' ability to assess their strengths and weaknesses in producing and recognising cardinal vowels. The data collected in the first testing sessions indicate that there is a clear link between perceived confidence and the ability to produce cardinal vowels and the ability to recognise them in a perception test, but there were some sounds that the participants felt overly confident about in relation to their actual performance and the other way round. For example, with regards to vowel production, the participants seemed to feel overly confident about their ability to produce cardinals [e] and [a] while reporting less confidence with regards to producing cardinals [ø] and [ɶ] than was reflected in their performance. In addition, as far as perception is concerned, the participants were overly confident about their ability to recognise [ɒ] and [ɯ] while correctly identifying [ɛ], [ɔ] and [œ] much more often than one might expect based on their self-reported sense of confidence. The participants in Whitworth's (2008a, 2008b) study also did not report [a] as a particularly difficult sound to produce and one of the groups she studied did not report [e] as one of the most challenging sounds to produce, while her participants did rate cardinal 10 as the second most difficult sound to produce ([ɶ] was not included in Whitworth's survey). Whitworth's (2008a, 2008b) participants were also relatively confident about their ability to recognise [ɒ] and [ɯ] while being less confident about being able to identify cardinals [ɛ], [ɔ] and [ø].

The findings of this study and the extent to which these findings agree with Whitworth's (2008a, 2008b) data regarding students' confidence ratings suggest that although students are often able to assess their own performance effectively, there may be problems which they are unaware of with certain sounds, particularly a tendency to be over confident with the open and close vowels. The students were also generally under confident with the close-mid and open-mid vowels. This research therefore indicates that lecturers teaching practical phonetics should make sure that students are not complacent about open and close vowels, and perhaps receive more positive reinforcement where the close-mid and open-mid vowels are concerned.

In terms of the fifth research question, if one compares the findings from the first and second testing sessions, it is seen that the participants retained their ability to perform and identify cardinal vowels very well over the seven-month period. This is in agreement with Crookston's (1999) finding that SLT graduates retain their knowledge of the IPA chart symbols needed to transcribe RP well over a period of 2.5–3.5 years. The fact that the participants' performance in the second perception test was so strong overall should give clinical phonetics lecturers a sense of satisfaction; it appears that practical phonetics skills well acquired on a relevant module are not lost very quickly. The participants' performance in the second production tests was, however, slightly worse and the variation between the participants in the autumn term tests was greater as evidenced in the standard deviation of 10.3 for the second tests as compared to 4.1 for the first tests. It is also important to note that one participant performed worse in her second perception test. On balance it seems appropriate to conclude that the participants in this study appear to have retained their ability to produce and identify cardinal vowels well over the seven-month period, but it is also clear that there may be significant variation between individual students as participant 2's lower scores in the second production and perception tests and the difference in the standard deviation between the first and second production tests show.

Turning now to assessing the limitations of this study and implications for future research, the main limitation with this study was the very small number of participants. A larger sample size would have allowed the use of inferential statistical methods of analysis which would have made the evidence used to support the conclusions stronger. In this light it is clear that the findings of the present study must be treated with some caution, especially as regards the findings concerning the relationship between the students' performance and confidence ratings, and that there is scope for further acoustic work involving larger groups of participants.

One limitation of the format of the tests used was that they only tested the participants' ability to recognise cardinal vowels auditorily in isolation. It would be interesting to study their ability to recognise them in context and when the speaker can be seen also. Another slight limitation was that the participants, although they studied the same module, were taught in different groups and in the case of one student by a different lecturer and were thus not exposed to identical instruction.

It is recognised that all the participants in the present study completed the same module where a particular syllabus is in place. Further research into the impact of the syllabus on the results would be very welcome, particularly with regards to whether students who revisit cardinal vowels during their programme of study end up even more proficient in performing and identifying them than students who do more intensive work on cardinal vowels during one academic year but have no further tuition after that. It would also be interesting to study the effect of different teaching approaches on performance such as whether students who have access to interactive online resources perform better than those students who rely solely on traditional classroom teaching and materials. It would likewise be relevant to study how well SLTs retain their practical phonetics skills in the long-term after they graduate.

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Appendix 1: The formant values obtained from the recordings made in the two testing sessions and from the recordings supplied by the two lecturers (speaker numbers correspond to participant/lecturer numbers)

Test 1 (Spring) measurements (all formant values in Hz)

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
1	1	305	3054		
1	2	741	2216		
1	3	758	2266		
1	4	892	1763		
1	5	741	1043		
1	6	523	1043		
1	7	372	825		
1	8	305	976		
1	9	305	2274	322	1887
1	10	506	1696		
1	11	356	1395		
1	12	590	1060		
1	13	523	825		
1	14	540	1395		
1	15	322	1361		
1	16	339	1143		
2	1	305	2685		
2	2	674	1814		
2	3	758	1814		
2	4	875	1378		
2	5	741	1311		
2	6	439	909		
2	7	456	1328		
2	8	289	1747		
2	9	286	2317		
2	10	439	1562		
2	11	439	1361		
2	12	490	993		
2	13	641	1060		
2	14	456	875		
2	15	439	909		
2	16	305	2065		
3	1	289	2803		
3	2	691	2300		
3	3	925	2233		
3	4	942	1328		
3	5	993	1328		
3	6	490	959		
3	7	490	892	322	657
3	8	322	1613	289	1428
3	9	322	2233		

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
3	10	473	2132		
3	11	557	1831		
3	12	590	1730		
3	13	657	959		
3	14	942	1445		
3	15	557	1914		
3	16	406	2409	339	2367
4	1	339	2970		
4	2	339	2870		
4	3	808	2333		
4	4	1076	1730		
4	5	825	1110		
4	6	741	1110		
4	7	423	892		
4	8	289	875		
4	9	339	2853		
4	10	305	2375	506	2317
4	11	791	2317		
4	12	1127	2032	875	1518
4	13	892	1445		
4	14	892	1479		
4	15	674	1127		
4	16	356	925		
5	1	289	2870		
5	2	708	2384		
5	3	791	2032		
5	4	993	1529		
5	5	909	1110		
5	6	540	942		
5	7	372	808		
5	8	339	791		
5	9	289	1847	322	2367
5	10	506	1931		
5	11	439	2065		
5	12	741	1311		
5	13	674	1043		
5	14	475	1261	609	1277
5	15	506	1043		
5	16	439	775		
6	1	272	2819		
6	2	657	2283		
6	3	641	2233	408	2333
6	4	791	2048		
6	5	791	1713		

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
6	6	808	1127		
6	7	540	892		
6	8	289	825		
6	9	256	2266	272	1579
6	10	506	1847		
6	11	607	1847		
6	12	708	1562		
6	13	741	858		
6	14	590	1378		
6	15	557	1344		
6	16	573	1395		

Test 2 (Autumn) measurements (all formant values in Hz)

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
1	1	408	2964		
1	2	559	2560		
1	3	912	2224		
1	4	1114	1669		
1	5	996	1265		
1	6	559	1047		
1	7	458	862		
1	8	324	1181		
1	9	307	1215		
1	10	576	1652		
1	11	559	1635		
1	12	963	1215		
1	13	710	1232		
1	14	374	1047		
1	15	441	1080		
1	16	424	996		
2	1	290	2712		
2	2	710	2106		
2	3	710	2123		
2	4	1030	1417		
2	5	929	1333		
2	6	744	1148		
2	7	542	996		
2	8	307	1871		
2	9	307	2661		
2	10	441	963		
2	11	424	862		
2	12	408	828		
2	13	744	1215		
2	14	441	895		

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
2	15	509	879		
2	16	290	1854	273	1618
3	1	307	2745		
3	2	525	2627		
3	3	727	2426		
3	4	1114	1652		
3	5	525	946		
3	6	828	1198		
3	7	929	1349		
3	8	794	1148		
3	9	408	1467		
3	10	475	2442		
3	11	694	2476		
3	12	744	2224	744	1938
3	14	424	609		
3	15	946	1450		
3	16	273	2695		
4	1	391	3081	559	2846
4	2	694	2442		
4	3	694	2089		
4	4	912	1988		
4	5	778	1265		
4	6	727	1215		
4	7	710	1013		
4	8	408	694		
4	9	441	2442		
4	10	677	2173		
4	11	677	2072		
4	12	879	1719		
4	13	744	1299		
4	14	710	1131		
4	15	710	1097		
4	16	660	946		
5	1	340	2796		
5	2	643	2426		
5	3	593	2072		
5	4	929	1400		
5	5	542	1198		
5	6	458	1063		
5	7	458	778		
5	8	307	828		
5	9	290	2846		
5	10	475	2224		
5	11	525	2140		
5	12	542	1366		
5	13	475	1097		
5	14	475	946		
5	15	391	1181		
5	16	424	1114		

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
6	1	324	2779		
6	2	559	2257		
6	3	761	2157		
6	4	996	1702		
6	5	862	1215		
6	6	559	996		
6	7	525	963		
6	8	424	1013		
6	9	324	1988		
6	10	525	1702		
6	11	559	1719		
6	12	727	1383		
6	13	660	1030		
6	14	626	1232		
6	15	660	1198	525	1030
6	16	509	1265		

Measurements obtained from the lecturers' recordings (all formant values in Hz)

Speaker	Vowel	*F1* (onset or nucleus)	*F2* (onset or nucleus)	*F1* (glide, if any)	*F2* (glide, if any)
7	1	339	2434		
7	2	356	2434		
7	3	557	1546		
7	4	858	1445		
7	5	523	993		
7	6	423	791		
7	7	372	775		
7	8	322	573		
7	9	289	2199		
7	10	305	1831		
7	11	356	1462		
7	12	775	1244		
7	13	506	825		
7	14	624	993		
7	15	356	942		
7	16	339	993		
8	1	406	2836		
8	2	490	2384		
8	3	724	2283		
8	4	1131	1837		
8	5	727	1097		

8	6	525	811
8	7	458	710
8	8	324	727
8	9	324	2476
8	10	475	2224
8	11	643	2005
8	12	710	1854
8	13	593	862
8	14	525	1131
8	15	458	1148
8	16	441	1198