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English vowel productions by Dutch talkers: more evidence for the "similar" vs "new" distinction

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1 Introduction

Most adults who learn a foreign language speak it with a discernible foreign accent (see e.g. Tahta–Wood–Loewenthal 1981; Flege 1988a). An issue that has motivated a great deal of second language (L2) research is whether foreign accent in adults is due to their having passed a sensitive period for speech learning. (See Snow 1988; Flege 1987b; and Johnson–Newport 1989, for recent discussions of this complex issue.) Speech learning requires the ability to establish central perceptual representations for a range of physically different phones ("sounds") which signal differences in meaning, and the development of motoric routines for outputting sounds in speech production. If a sensitive period for human speech learning exists then, by hypothesis, adults may be less able than young children to learn to pronounce and perceive an L2 (or do so at such a slow rate that it appears that their speech learning ability has diminished).

The observation which has motivated much of my research is the following paradox: why should most sensorimotor skills increase through adolescence but those underlying speech learning decrease? (See e.g. Politzer–Weiss 1969; Olson–Samuels 1973; Smith 1977; Snow–Hoefnagel-Höhle 1982a; Ekstrand 1982.) An increasingly prevalent view in psycholinguistics is that speech and language processes are effected by distinct "modules". Even if one assumes that, say, one's ability to identify the notes in a tune and then to reproduce them by whistling is separate and distinct from the ability to reproduce L2 *sounds*, it is difficult to understand why a speech-language module should be especially vulnerable to the ravages of time. I think it more likely that the basic processes and mechanisms that guide successful speech learning during L1 acquisition remain intact well into adulthood, but that foreign accent persists in the speech of many adults who learn an L2 because of factors that are independent of changes in basic speech learning abilities.

Take, for example, the production of English stops by native speakers of French. Flege and Hillenbrand (1984) found that adult native French speakers of English produced English /t/ with voice onset time (VOT) values

that were shorter (and therefore French-like) than those produced by English monolinguals. Conversely, native English speakers produced French stops with VOT values that were longer (and therefore English-like) than French monolinguals'. There is indirect evidence to suggest that these subjects were able auditorily to detect the acoustic phonetic difference between French and English /t/s (Flege 1984; Flege–Hammond 1982). Direct support for this assertion is the finding that the L2 learners produced stops with appropriately different VOT values in their two languages.

A sensitive period hypothesis might be used to account for the "compromise" VOT values seen in the speech of the native French and English L2 learners. There are, however, two problems with a sensitive period explanation. It provides no explanation for why the L2 learners examined by Flege and Hillenbrand (1984) only *partially* approximated the L2 English phonetic norm. Why should it be any easier to modify laryngeal timing to give the approximately 20-ms changes in VOT that were observed, than to learn a modification that would give the approximately 40-ms increase needed to *achieve* the phonetic norm of the L2? Moreover, a sensitive period hypothesis offers no insight into what specific speech learning mechanisms or processes are changed or attenuated as humans mature physiologically and develop cognitively.

The speech production data now available make it appear likely that previous L1 learning affects subsequent L2 learning through the intermediary of central cognitive-linguistic and phonetic structures more abstract than the sensorimotor level implied by a sensitive period hypothesis. A second-language "Speech Learning Model" (henceforth SLM) incorporating this point of view has been developed (Flege 1980; 1981; 1987a; 1987b; 1988b; 1992). A complete description of the SLM falls outside the scope of this chapter, but it is important to note that most empirical support for the SLM to date [viz., 1990–JEF] has come from the study of consonant production. The purpose of the present chapter is therefore to present the results of a vowel production study that provided an additional test of the model.

A hypothesis generated by the SLM is that the phonetic categories needed to produce and perceive L2 sounds can be added readily until the age of 5–6 years, when the phonetic system begins to stabilize. After that age, additional categories can be established for "new" but not for "similar" L2 sounds. Although both new and similar L2 sounds differ acoustically from sounds in the L2, there is thought to be a qualitative as well as a quantitative difference in the degree of phonetic dissimilarity between these two types of L2 sounds and sounds found in the L1. The distinction between new and similar sounds will be described further below. For now, suffice it to say that a *new* L2 sound is one that differs sufficiently from any sound in L1 that it evades the effects of equivalence classification (a basic cognitive mechanism thought to shape both L1 and L2 speech learning) whereas *similar* L2 sounds do not.

The present study examined production of the English vowels /i/, /æ/, /ɑ/, /u/, /ɪ/, and /ʌ/ by 50 Dutch university students. A previous study (Flege–Eefting 1987) showed that all 50 students had a detectable foreign accent even though many were majoring in English at a Dutch university and presumably had frequent access to native speakers of English. The Dutch students' success in learning English vowels was assessed primarily by determining how often each vowel was identified by native English-speaking listeners. The SLM leads to the prediction that the Dutch subjects would be more successful in learning new than similar English words.

1.1 Perceptual Limitations

The prediction of differential success for new and similar vowels derives from limitations that are largely perceptual in nature.[1] It is generally assumed that L2 learners will identify certain sounds in the L2 with sounds from the L1 even when detectable acoustic differences exist (see e.g. Weinreich 1953; Brière 1966; Wode 1977; 1978; also Best et al. 1988). Trubetzkoy (1932/1969) hypothesized that the phonology of L1 causes L2 learners to filter out acoustic differences that are not phonemically relevant in L1 (see also Borden–Gerber–Millsark 1983). Logan et al. (1989) observed that learning a nonnative contrast may be difficult because children's perceptual sensitivity to speech changes as the result of experience so that only those phonetic contrasts that "denote differences in meaning" will remain distinctive.

An important issue is whether interlingual identification persists even after the L2 learner has gained thorough familiarity with the sound structure of the L2. If so, physically different L2 sounds are said to have been "equated". Equivalence classification is a basic cognitive mechanism which enables talkers, for example, to use the word *chair* correctly in identifying the many physical exemplars of this furniture type. Equivalence classification is also very important for speech learning because it permits listeners to make perceptual groupings of a wide variety of disparate phones with a common communicative function. The effects of equivalence classification are evident in prelinguistic infants (see e.g. Kuhl 1979; Hillenbrand 1983, 1984) and permit children and adults to perceive constant phonetic categories in the face of variability found in the many physical exemplars which may instantiate a

category. A tenet of the SLM is that certain L2 sounds (viz., the new sounds) will eventually evade equivalence classification. Another is that the propensity for equivalence classification increases after about the age of 5–6 years.

Children learning an L1 are faced with the question of how best to classify sounds found in the ambient language. A large cognitive learning task awaits the child acquiring L1 phonology, even after phonetic categories have been established and methods found for implementing them. Children must discern what are the *phonemic* categories of their L1 (Ferguson 1986). Jusczyk (1989) notes that even after children have arrived at a "correct description" of the phonetic categories found in their L1, they still face an additional "mapping problem" that involves relating phonetic categories to the phonological categories of the L1. For native English children this involves, among other things, learning that [t^h] and [t] are context-sensitive allophones of the /t/ phoneme.

The SLM predicts that older L2 learners will be less successful in learning similar L2 sounds than younger L2 learners because they equate similar L2 sounds with sounds in the L1. Although it is uncertain why young children should treat similar L2 sounds differently than older L2 learners, one potential basis for the hypothesized difference is that adults and older children may make greater use of higher-order syntactic and semantic information than young children. Auditory-acoustic processing of the speech signal might be terminated prematurely in adults and older children as the result of more rapid word recognition which is brought about by greater (or earlier) use of higher-order linguistic information in parallel with bottom-up phonetic information.

Another possibility is that a difference between young and older L2 learners occurs because of the *state of development* of phonetic categories at the time L2 learning commences. As children encounter an increasingly wide range of phonetic category realizations, they may become better able to identify sounds in non-ideal listening conditions because the tolerance limits of the category expand. Although such a development should be regarded as highly adaptive as far as processing of the L1 is concerned, it may make it harder to note purely phonetic differences between similar L1 and L2 sounds. For example, a native Spanish 5-year-old may be better able than a native Spanish adult to note the acoustic difference between the [t] and [t^h] phones used to realize /t/ in Spanish and English. At the same time, the "prototype"of each category may become better defined. This may make it easier for children, as they grow older, to detect distortions and to gauge degree of foreign accent (see Flege 1988a).

Jusczyk (1985) suggests that variants in complementary distribution, such as word-initial [t^h] and word-final [t], will not be associated in a single phonemic unit until children learn to read. This is consistent with the classic view of perceptual development which suggests that children become increasingly less reliant on sensory information as they develop cognitively and learn to ignore attributes of sensory stimuli that are irrelevant to classification (Gibson 1969). Learning to focus attention on just those aspects of sounds needed for phonemic contrasts also seems to characterize the perception of L2 sounds by adults.

Lambert (1977) suggested that some L2 learners ("code users") are likely to perceive an L2 sound which differs auditorily from sounds in the L1 in terms of L1 categories, whereas others ("code formers") tend to develop new central representations. These terms were used to differentiate adult learners, and might be useful for accounting for why some adults profit more than others from auditory perceptual training on a novel phonetic contrast (see e.g. Flege 1989a; Flege–Wang, 1990). These terms might also serve to distinguish – in a general sense – adult from child learners. That is, adults may be generally more likely to equate L2 sounds with sounds from the L1 even though their discriminatory abilities are no less keen than young children's.

An increasing tendency to equate physically disparate sounds may facilitate speech perception. Jusczyk (1989) suggested that children may perform deeper and more abstract analyses of the acoustic signal as their lexicons expand to include an ever larger number of phonetically similar words. That is, the presence of phonetic near-neighbors may encourage young children to recognize the existence of new phonetic groupings of sounds that serve to differentiate meaning. With this comes the implication that the tendency to segment words into sounds may increase. Burnham (1986) found that children with good comprehension abilities for their age were more likely to identify sounds in accordance with the phonemic categories of their L1, and to ignore phonetic contrasts that were not phonemically relevant in L1, than were children with relatively poor comprehension abilities.

A developmental increase in the tendency to equate similar L2 sounds with sounds in the L1 might be encouraged by greater phonemic awareness, which seems to increase at about the time children learn to read (Liberman et al. 1974; Bradley–Bryant, 1983). Learning to read may further encourage a segmental level of analysis (Morais et al. 1979; Mann 1986; Kirtley et al. 1989; Bradley–Bryant 1983) which in turn may be related to a propensity for equivalence classification (Mann 1984; Brady–Shankweiler–Mann 1983). Mann (1984) concluded that good and poor readers differ in terms of how effectively they use phonetic representations to process speech.

It is important to note that the SLM differs from previous approaches in not regarding equivalence classification as a kind of auditory or phonological "filter" of subphonemic acoustic differences between L1 and L2 sounds. By hypothesis, all audible acoustic differences between similar L1 and L2 sounds may influence the phonetic system, even those that are not available perceptually. So, to return to the example cited above, native French adults who are highly experienced in English may produce English /t/ with compromise VOT values because they are unable to establish a long-lag stop category for English /t/ as the result of equivalence classification, not because they are unable to detect auditorily the acoustic differences between French and English stops. The SLM leads one to expect that their phonetic category prototype for /t/ has changed because of the many English [t^h] they have identified as /t/.

1.2 The new vs similar distinction

A useful method for characterizing the relationship between sounds in L1 and L2 is to classify the L2 sounds as "new", "similar" or "identical". Such a three-way classification is implicit or explicit in much L2 research (see e.g. Brière 1966). For example, Delattre (1964, 1969) noted that some sounds in an L2 differ "radically" from any sound in the L1 and should be regarded as "new" from the standpoint of the L2 learner. Wode (1978, p. 114) noted that a major difference between child and adult learners of an L2 is "the state of development" of their phonological systems. In his view, both children and adults match phonic elements of the L2 to their L1 "grid". As the L2 is processed, the acoustic input is "scanned" and phones falling within some "crucial similarity range" are judged to be equivalent to an element of L1, and therefore substituted by it. Other phones falling outside a crucial (but undefined) range are judged to be non-equivalent, and will undergo "other developments" than simple substitution, according to Wode.

The SLM posits that the basis for a sensitive period is the increasing frequency of equivalence classification by older children and adults compared to young children. One might characterize L1 learning by young children as a "bottom-up" process of learning, whereas L2 learning by older children and adults might better be characterized as a "top-down" process (Mack 1989). For young children acquiring an L1, *all* sounds are new. The number of phonetic categories they will establish depends on the number of sounds encountered in the L1. Older children and adults who are learning an L2, on the other hand, have already established a phonetic system suitable for distinguishing a large (and ever-growing) number of lexical items. The number of additional categories they establish will be limited by their previous phonetic learning via the mechanism of equivalence classification.

No universally-accepted method now exists for differentially classifying L2 sounds as new or similar. In attempting to operationalize this distinction, the most important question to consider is: when does an acoustic difference between L1 and L2 constitute a *phonetically relevant* difference? To determine this, the SLM now [i.e., when this chapter was written in 1990 – JEF] employs three criteria for classification.

A preliminary step is to consider the IPA symbols used to represent sounds of the L1 and L2. This is followed by acoustic measurements and listeners' perceptual judgements of sounds in L1 and L2. The SLM posits that interlingual identification occurs at a phonetic rather than phonemic level, so the procedures operate on sounds (that is, phonetically-relevant phone classes).

An *identical* L2 sound is represented by the same IPA symbol used to represent a sound in the L1. When acoustic analyses are performed for representative native speakers, there is not a significant acoustic difference between the L2 sound and its counterpart in L1; and listeners cannot detect a difference between the L1 and L2 sounds when a detailed perceptual analysis is performed. An identical L2 sound is usually produced authentically as the result of a process referred to as "positive transfer" (Weinreich 1953). Identical sounds have therefore received little attention, because most L2 speech errors involve similar and new sounds (James 1984).[2]

To be classified as either similar or new, some acoustic difference(s) between pairs of L1 and L2 sounds must exist, and there must be evidence that the sounds are auditorily discriminable. A "phonetic symbol" criterion is used because, at present, no accepted metric exists for measuring the phonetic distance between sounds in two languages. An L2 sound that is *similar* to a sound in L1 is represented by the same IPA symbol as the L1 sound, even though statistical analyses reveal significant – and audible – differences between the two.[3]

An L2 sound that is *new* differs acoustically and perceptually from the sound(s) in L1 that most closely resemble(s) it. But, unlike a similar sound, it is represented by an IPA symbol that is not used for any L1 sound. An example of a new sound from the standpoint of English is French /y/. This vowel sound differs acoustically and perceptually from the nearest possible vowels of English (/i/, /I/, /u/), and is represented by a symbol not used traditionally in describing the vowels of English.

The phonetic symbol criterion is not, of course, without problems. Many phonetic transcription systems are now in use, and even seasoned researchers

who are using nominally the same system don't always agree. For example, the distinction between the vowels in the English word like *beat* and *bit* is sometimes represented as a distinction between /i/ and /I/, and sometimes as one between /i:/ and /i/. The latter symbolization, which emphasizes the duration difference that accompanies the spectral distinction between this tense-lax vowel pair, seems to be favored by analysts whose L1 makes important use of duration for phonemic distinctions.[4]

It thus appears necessary to supplement the phonetic symbol test with additional acoustic criteria. Bohn and Flege (1992) suggested that an L2 vowel should be considered new only if most of its realizations occupy a portion of the acoustic phonetic vowel space that is unoccupied by the realizations of any L1 vowel. This implies that few of the vowels in an L2 will be new for learners whose L1 has a large vowel inventory. Perceptual tests should also be used to differentiate new and similar vowels. Other behavioral measures of speech processing might also furnish a useful metric, as illustrated by Flege (1992).

2 Dutch vs English vowels

The present study examined Dutch subjects' production of six English vowels which, from the standpoint of Dutch, included vowels that might be classified as "identical", "similar", or "new". Four of the vowels defined the corners of the vowel quadrilateral (/i, æ, ɑ, u/), one was a high front lax vowel (/I/), and the remaining vowel was a short, central vowel (/ʌ/).

Dutch is usually analyzed as having three diphthongs (/ɑu/, /ʌy/, /ɛi/) and 12 monophthongs, which Moulton (1962) divided into two classes based primarily on phonological considerations: short (/ɔ/, /ɑ/, /æ/, /I/, /ɛ/) or long (/i/, /u/, /y/, /o/, /a/, /ø/, /e/). Duration measurements have shown, however, that except before /r/, three of the supposedly long vowels (/i/, /y/, /u/) are short (Nooteboom 1972; Nooteboom – Slis 1972). In addition Dutch has three long vowels that occur in foreign loan words (/ɔ:/, /œ:/, /ɛ:/) and a schwa (/ə/) in unstressed syllables.

Figure 1 shows the acoustic relationship between the six English vowels examined in the present study and the 12 Dutch monophthongs that occur in stressed syllables. The ellipses for English /i/, /I/, /æ/, /ʌ/, /ɑ/, and /u/ represent 95 % confidence intervals drawn around the F_1–F_2 values for Dutch vowels. They are based on values reported for 50 adults male native speakers of Dutch by Pols et al. (1973).

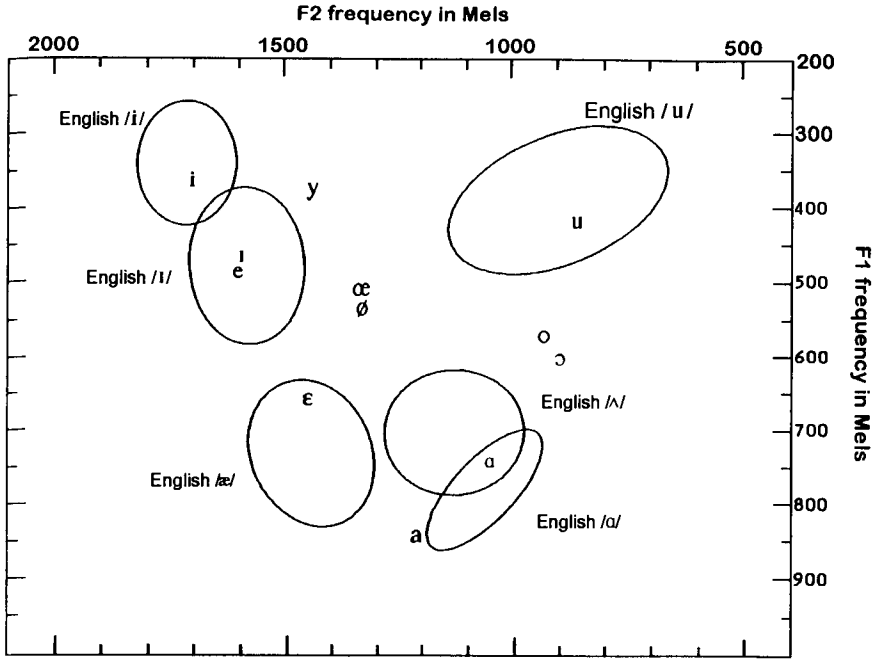

Figure 1. Acoustic relationship between American English /i/, /I/, /u/, /ɑ/, /æ/, /ʌ / and Dutch vowels. The ellipses for the English vowels surround approximately 95 % of the F_1 and F_2 values reported by Peterson–Barney (1952) for 33 male English speakers. The ellipses were drawn through four points located two standard deviations from the intersection of axes defining the two principal components of variation. The phonetic symbols represent the mean F_1 – F_2 values reported by Pols, Tromp and Plomp (1973) for 12 monophthongal Dutch vowels spoken by 50 native Dutch men.

Figure 2 shows the relationship between the Pols et al. (1973) Dutch vowel data and the mean values reported by Holtse (1972) for English vowels as spoken by six male native speakers of British English (henceforth BE). The BE males were speakers of general Received Pronunciation.

2.1 An identical vowel

English /I/ was classified here as identical. As seen in Figures 1 and 2, the mean values for Dutch /I/ are very similar to those reported for the /I/ of AE and BE. An ANOVA carried out by Disner (1983) showed that the F_1–F_3 values for Dutch /I/ (Pols–Tromp–Plomp 1973) and AE /I/ (Peterson–Barney 1952) did not differ significantly. It appears that the /I/s of Dutch and

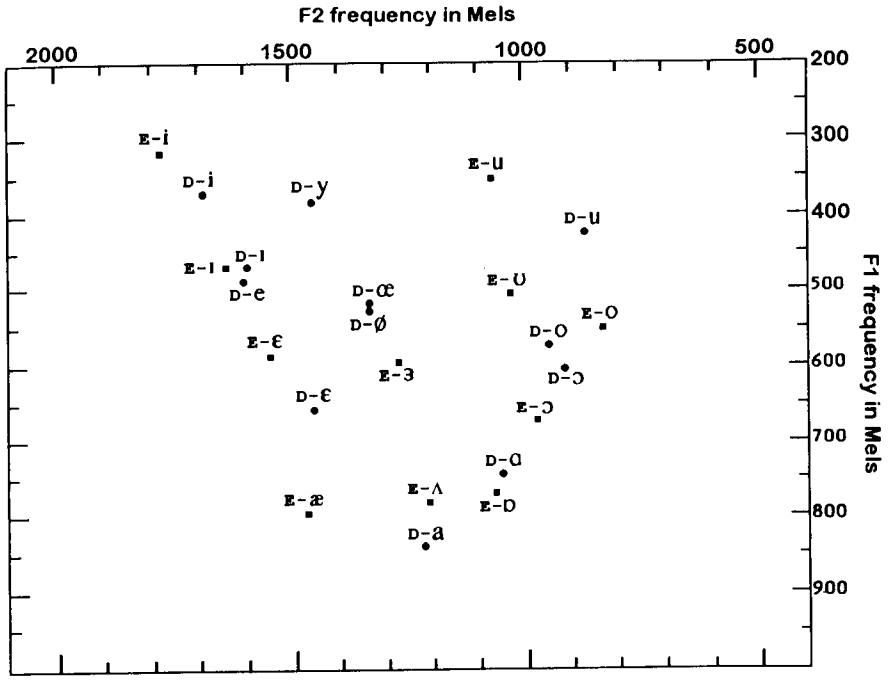

Figure 2. Mean values for Dutch vowels (marked "D") reported for Dutch men by Pols–van der Kamp–Plomp (1969) and for English vowels (marked "E") reported for six British male speakers of RP by Holtse (1972).

BE do not differ auditorily. Collins–Mees (1984, p. 86) stated that Dutch /I/ can "pass straight into (British) English without being modified" and should thus pose "no problem" for pronunciation.[5]

2.2 A new vowel

English /æ/ was classified here as new because Dutch has no vowel phoneme realized phonetically as /æ/. As seen in Figure 1, the mean values for Dutch /ɛ/ tokens fall within the upper portion of the space occupied by English /æ/. Figure 2 shows that BE /æ/ is more distant from a Dutch vowel than any other BE vowel. Collins and Mees (1984) observed that both beginning and advanced Dutch learners substitute Dutch /ɛ/ for English /æ/ (see also van Heuven 1986), but they did not quantify this observation.

Perceptual data reported by Schouten (1975) are consistent with the belief that Dutch learners of English will eventually recognize that English /æ/ is a new, non-Dutch vowel. Results were obtained from both advanced (3rd and 4th year) and beginning (1st year) Dutch students majoring in English at the University of Utrecht. The advanced students identified /æ/ correctly more often than the beginning ones (93% vs 57% correct). Not surprisingly, the only consistent error was /ɛ/ (12% of responses).

2.3 Similar vowels

English /i/ was classified as similar because Dutch /i/ is lower in the acoustic space than either the /i/ of AE or BE. Disner (1983) found that the F_1–F_3 values of Dutch /i/ and AE /i/ differed significantly. Consistent with this, Collins and Mees (1984) stated that Dutch learners typically substitute Dutch /i/ for English /i/ even though the Dutch vowel is "less fronted" than its English counterpart.

English /u/ was classified as a similar vowel, but may pose more of a learning problem for Dutch L2 learners than English /i/. Dutch /u/ differs acoustically from English /u/ (Disner 1983) and has been described as intermediate to the /u/ and /U/ of English (van Heuven 1986). Dutch learners may at first substitute Dutch /u/ for English /u/. More advanced Dutch learners are said to substitute the vowel "sequence" /yu/ for English /u/ (Collins–Mees 1984), perhaps because /u/ is fronted so much in BE that some actually regard it as a *front* vowel (Bauer 1985). In a study by Schouten (1975), Dutch students identified synthetic English /u/ tokens in only 60% of instances; most misidentifications of /u/ were as /U/.

English /ʌ/ would be classified as a new vowel if the only criterion applied was a consideration of phonetic symbols, for Dutch has no vowel phoneme represented as /ʌ/. However several considerations led to the classification of /ʌ/ as similar. First, acoustic data suggest that English /ʌ/ occupies a portion of the acoustic phonetic vowel space that goes unused in Dutch. As seen in Figure 1, the mean values for Dutch /ɑ/ fall within the area occupied by AE /ʌ/; and the same appears to be true for BE vowels. As seen in Figure 2, the BE /ʌ/ is spectrally close to the short Dutch vowel /ɑ/, and even slightly closer to the long Dutch /a/.[6]

There is anecdotal evidence that as Dutch speakers become more experienced in their L2, they continue to identify English /ʌ/ with a vowel(s) of Dutch. Van Heuven (1986) indicated that Dutch L2 learners identify English /ʌ/ with the Dutch /œ/; and Collins and Mees (1984) indicated that even though the mid-high front rounded Dutch vowel /œ/ and BE /ʌ/ are "very different" from /ʌ/, inexperienced Dutch learners of English substitute the Dutch

/œ/ for English /ʌ/ and experienced Dutch L2 learners tend to substitute the short Dutch vowel /ɑ/ for /ʌ/.[7] Data reported by Schouten (1975) also suggests that interlingual identification persists. Dutch students identified /ʌ/ correctly less often than /æ/ (41% of instances as compared to 80% for synthetic /æ/s). There was only a small difference in the rates for /ʌ/ obtained for advanced and beginning students (48% vs 32%).

Classification of the vowel in the word *hot,* represented here as /ɑ/, is complicated by the fact that it is realized as a central, unrounded vowel (/ɑ/) in AE but as a slightly rounded *back* vowel /ɒ/ in checked syllables in BE (Wells 1982). Figure 1 shows that AE /ɑ/ is similar spectrally to the long Dutch vowel /a/, but tests performed by Disner (1983) indicated that these vowels had significantly different F_1 and F_3 (but not F_2) frequencies. Since AE /ɑ/ is more distant from the short than the long Dutch /ɑ/, it is likely that acoustic differences between Dutch /ɑ/ and AE /ɑ/ would also be significant.

It thus appears that, from the standpoint of Dutch, AE /ɑ/ may be treated as a similar vowel. Figure 2 shows the acoustic relationship of /ɒ/ – the BE equivalent to AE /ɑ/ – to Dutch vowels. BE /ɒ/ is close to Dutch /ɑ/ in the $F_1 - F_2$ space, but is considerably longer (see Holtse 1972) than Dutch /ɑ/, which Nooteboom (1973) suggests is represented centrally by Dutch speakers as being half the length of /a/. It is probably because of this temporal mismatch that even highly proficient Dutch L2 Learners continue to substitute Dutch /ɔ/ for BE /ɒ/ (Collins – Mees 1984).[8]

3 Predictions of the model

Early L2 learners are defined as individuals who begin learning the L2 before the offset of the sensitive period at about the age of 5–6 years; Late L2 learners are those who begin learning their L2 later in life.

The SLM posits that phonetic categories are needed for the fully authentic production of L2 sounds. By hypothesis, Early L2 Learners are able to establish phonetic categories for all L2 sounds not found in the L1, and so possess an enriched phonetic system which includes the phonetic categories possessed by monolingual speakers of both the L1 and the L2. This leads to the hypothesis that Early L2 learners will produce identical, similar, and new L2 sounds authentically.

The SLM posits that Late L2 Learners will differ from Early L2 Learners with respect to similar sounds but not to identical and new sounds. This position diverges from the ones taken by some previous investigators. Stockwell and Bowen (1965; see also Olson–Samuels, 1973), for example, suggest that

the *absence* of an L2 sound in the L1 will be the source of the greatest learning difficulties, whereas the existence of an L2 sound in the L1 generally *facilitates* learning. According to Brière (1966, p. 795), L2 sounds with "close equivalents" in the L1 sounds will be "easier to learn" than L2 sounds that are more distant from any sound in the L1. Oller and Ziahosseiny (1970), on the other hand, argued that L2 sounds that differ *minimally* from sounds in the L1 are more difficult to learn than those which differ substantially from L1 sounds.

There may be an element of truth in both positions. Results reported by Snow and Hoefnagel-Höhle (1982) suggest that L2 sounds with close equivalents in L1 may be relatively easy to produce in early stages of L2 learning, whereas more dissimilar L2 sounds may be difficult in the early stages of learning because they require new modes of phonetic implementation, but may be produced more authentically in later stages. Such a prediction follows from the hypothesis that Late L2 Learners are eventually able to establish phonetic categories for new L2 sounds whereas they will never be able to do so for similar L2 sounds.

Late L2 learners may, at first, identify new sounds with some sound(s) in the L1, but this will not persist because the new L2 sound will not be equated with an L1 sound. It is predicted that Late L2 Learners will, given sufficient phonetic input, note the phonetic difference between a new L2 sound and neighboring sounds in L1, and that this will precipitate the establishment of a phonetic category for the new L2 sound. Once a realization rule has been developed with which to output the newly established L2 category, production of the L2 sound will be authentic.

In the study presented here, the Dutch subjects who spoke English with good accents were expected to produce new English vowels more authentically than those who spoke English with poor accents owing to more (or better) L2 phonetic input. Equivalence classification was hypothesized to block the formation of phonetic categories for similar English vowels but not new English vowels for these Late L2 Learners. A prediction generated by the SLM was that the Dutch subjects would only approximate English phonetic norms for *similar* vowels regardless of how much native-speaker phonetic input they had received (see Flege 1981; 1984; 1988b; Flege–Hillenbrand 1984). Another prediction was that the Dutch subjects with good accents would produce new English vowels more authentically than Dutch subjects with poor accents, but would not differ from the subjects with poor accents in producing *similar* L2 sounds. This derived from the hypothesis that Late L2 Learners are able to establish phonetic categories for new but not for similar L2 sounds.

4 Previous research

Relatively few previous studies of L2 learning have provided data suitable for evaluating the SLM's predictions concerning vowel production. An /ɛ/-for-/æ/ substitution was reported for Bulgarian-accented English speakers by Danchev (1987) at first seems to contradict the SLM's predictions. Bulgarian is analyzed as having /ɛ/ and /ɑ/ phonemes but no /æ/ (Maddieson 1984), leading one to think that /æ/ is a new vowel and will therefore be produced authentically by Bulgarians who are experienced in English. Danchev (1986) reported, however, that Bulgarians substitute their /ɛ/ (and, less frequently, /ɑ/) for English /æ/. He noted that an /ɛ/-for-/æ/ substitution may be "consciously or unconsciously accepted" by native English listeners and Bulgarian teachers of English because of the acoustic overlap seen between /ɛ/ and /æ/ in British English (henceforth BE). The substitutions in Bulgarian-accented English probably do not represent a disproof of the prediction about new vowels, however.[9]

Predictions derived from the SLM were supported by two recent studies of L2 vowel production. Flege (1987a) measured formant frequencies to test the difference between similar and new vowels in French, viz. /u/ and /y/. Previous research had suggested that English speakers substitute English /u/ for the new French vowel /y/ in early stages of L2 learning, but little was known concerning how experienced English speakers of French would perform. The most experienced of the three native English groups examined did not differ from French monolinguals in producing the new vowel /y/, whereas all three groups differed from French monolinguals in producing the similar vowel /u/.

Perceptually-based results obtained by Major (1987) suggested that new vowels may be learned more successfully than similar vowels. That study examined the production of English /æ/ and /ɛ/ by 50 Brazilian subjects. From the standpoint of Portuguese, English /æ/ is apparently a new vowel and English /ɛ/ is a similar vowel.[10] If so, then the SLM predicts that Portuguese learners of English will establish a phonetic category for English /æ/, and eventually produce that vowel authentically, whereas they will be unable to establish an /ɛ/ category and thus will continue to produce that vowel nonauthentically.

Native English-speaking subjects in the study by Major (1987) identified /æ/ (in *sat*) and /ɛ/ (in *bet*) in a two-alternative forced-choice test. The percentage of correct identifications was calculated for two groups of Brazilian subjects differing in overall degree of foreign accent. The relatively non-proficient subjects' /ɛ/ was more intelligible than their /æ/ (87% vs 26% correct identifications), whereas the reverse was true for the proficient subjects

(50% vs 68% correct). These differences led to a significant Group × Vowel interaction in an ANOVA examining the percent correct scores ($p < .01$).[11] It appeared that the Brazilians were learning English /æ/ but that their productions of English /ɛ/ had somehow deteriorated, perhaps because of system pressure from a newly-formed /æ/ category. A definite conclusion cannot be reached, however, because the listeners were offered only two choices, which means that results for one vowel necessarily affected results for the other vowel. The present study also used a perceptual method to assess the authenticity of L2 vowel production, but it made use of 14 rather than just two response choices.[12]

5 Methods

5.1 Talkers

The present study examined English vowels spoken by 25 male and 25 female native Dutch talkers whose production and perception of English stops was examined previously (Flege–Eefting 1987a). The Dutch talkers were Late L2 Learners between the ages of 20 and 25 years who began learning English at about the age of 12 years in school. Forty of them were students majoring in English at the University of Utrecht; the remaining 10 were students majoring in engineering at a technical school in Delft. These latter subjects had not studied English beyond the six years required in high school, and were consequently less proficient in English than were the English majors.

Of the eight native speakers of BE selected to define the "norm" for English, four females were recorded in Birmingham, Alabama and four males were recorded in Amsterdam. None of these talkers could speak Dutch; all could be described as speaking General R.P.[13]

5.2 Listeners

The vowels were identified by three native speakers each of BE and AE. The responses of two listener groups were collected because dialect differences between talkers and listeners lead to an increase in the frequency of vowel identification errors (see Macchi 1980). AE can be heard in the Netherlands on television and in popular music, but BE is taught in the school (sometimes by native BE talkers). Consequently, Dutch speakers of English often seem to Americans to have a "British" accent.

The AE listeners (A1–A3) were native speakers of AE. A3 was the author; A1 and A2 were part-time research assistants who participated in the experiment as part of their ordinary duties. The three BE listeners (B1–B3) were not speech researchers and were, accordingly, paid a nominal sum for participating. None of the listeners spoke Dutch or indicated familiarity with Dutch-accented English. None of the AE or BE listeners spoke with a marked regional accent.

5.3 Speech materials

The talkers produced test words formed by inserting the vowels /i/, /I/, /ɑ/, /u/, /ʌ/, and /æ/ into a /h_t/ frame. This yielded six real words (*heat, hit, hot, hoot, hut, hat*). The words were read from a randomized list at the end of the carrier phrase "Sip through a ___".

The utterances were recorded using high-quality equipment. Three tokens of each word from the middle of the list were low-pass filtered at 5 KHz, digitized at a 12 KHz rate with 12-bit amplitude resolution, and stored on disk. A waveform editor was used to discard all but the periodic portion (or "vowel") from each stored waveform to avoid lexical bias effects in the subsequent identification experiment (see e.g. Ganong 1980).[14] A disadvantage of the editing was that it was likely to decrease the overall rate of correct identifications due in part to the loss of temporal information (see e.g. Bond 1976).

5.4 Listeners' response categories

The listeners were told that they were to identify English vowels using 14 keywords listed on a response box in the following order: *heat, hoat*, foot, hit, hat, hoot, hate, hot, hurt, hite, hout*, het*, hut, hoit**. The four orthographic response categories marked by an asterisk are not real words in English, but all of the keywords conformed to English spelling conventions. Potentially confusable items such as heat and hit were not juxtaposed. The keywords represented all AE vowels except for /ɔ/ and /ə/. Schwa was excluded because it, like the Dutch schwa, does not occur in stressed syllables; and /ɑ/ was excluded because it did not contrast with /ɔ/ in the dialect of the AE listeners.

5.5 Pretest

It was necessary to familiarize the listeners with the testing procedure because there were so many response categories. After being given rhyming words for keywords that might be confused, the listeners were asked to point to keywords on the response box in response to the experimenter's live voice presentation of isolated vowels found in the 14 keywords. Once the listeners were able to respond correctly and confidently to the isolated live-voice vowels, they participated in a formal pretest.[15] The pretest made use of isolated test vowels prepared using the procedures described above. It consisted of the randomized presentation of three tokens of 14 vowels (all edited from /hVt/ words). The vowels presented to AE listeners were from words read by a native speaker of AE; those presented to the BE listeners were from words spoken by a native speaker of BE. To be entered into the study, a listener had to make two or fewer errors on the 42-item test on the first and second days of testing.[16]

5.6 Instructions

The listeners were told that they would hear vowels edited from /hVt/ words. The proportion of native and Dutch speakers was not specified. The BE listeners (unlike the AE listeners) were unaware that the talkers had actually spoken only six /hVt/ words, not all 14 listed on the response box. However, both the AE and the BE listeners were told to use all 14 response categories, as appropriate, and to guess if uncertain. The listeners positioned the lever on the response box next to one of 14 keywords to signal their judgments. The interval between the listener's response and the next vowel was fixed at 1.0 sec.

5.7 Stimulus presentation

The 1,044 vowel stimuli were normalized for overall RMS intensity and presented over TDH-49 headphones at a comfortable level (76 dB). The 18 stimuli (6 vowels x 3 tokens) for each talker were randomly presented three times each in a single block. The order of the talkers was counterbalanced across listeners. The listeners heard the vowels of about eight talkers per day over an approximately two-week period. At least one native English talker was presented along with the Dutch talkers on each day of testing. This yield-

ed a total of 3,132 responses from each listener (58 talkers × 6 vowels × 3 replicate tokens × 3 presentations).

5.8 Evaluating the talkers' degree of foreign accent

The foreign accent scores obtained previously for the Dutch talkers (Flege–Eefting 1987a) were used to group them according to their pronunciation of English.

The 50 Dutch talker and five native speakers of BE produced sentences containing sounds known to be problematical for Dutch speakers of English ("I can read this for you", "The good shoe fits Sue" and "The red book was good"). The sentences were digitized and randomly presented three times each to eight native speakers of BE residing in Birmingham, Alabama. In evaluating the 165 sentences, the listeners positioned a lever on a response box between endpoints marked "Strong foreign accent" and "No foreign accent". The response box returned values ranging from 1, for sentences that were strongly accented, to 256, for sentences pronounced authentically. The average foreign accent scores accorded the native BE talkers was 239 (SD = 9). The scores for the 40 Dutch talkers majoring in English averaged 178 (SD = 36), and those for the 10 Dutch engineers averaged just 86 (SD = 29).

The Dutch talkers who received the 16 lowest scores were assigned to the "Strong Foreign Accent" group. The 16 Dutch talkers with the highest scores were designated the "Mild Foreign Accent" group even though two of them received scores placing them in the native English range. (Data for two Dutch talkers were excluded to ensure an equal number of talkers in all three subgroups.) It is likely that the Dutch talkers with mild foreign accents had more English-language experience than those with strong accents. This assumption was supported by an analysis of stop consonant production.[17]

5.9 Intelligibility analyses

The dependent variable for each listener was the percentage of times (out of a maximum of 9 responses) that the vowels spoken by each talker were identified correctly. Mean percent correct scores were then calculated for the three BE and three AE listeners. These scores, which were based on 27 forced-choice identifications for each vowel, were analyzed in mixed-design Group × Vowel ANOVAs. Separate analyses were carried out for the AE and BE listeners because only the AE listeners had training in phonetics, and only

they were aware of which vowels the talkers had actually intended to produce. The percent correct scores were transformed using the arcsine transformation recommended by Kirk (1968). Since the results did not differ from the analysis of untransformed scores, the results of this second analysis will not be reported.

6 Results of the intelligibility test

6.1 American listeners

The results are summarized separately for each of the three American listeners in Table 1. The mean percentage scores presented here are based on the frequency with which each of the six vowels was identified correctly. The phonetic symbols indicate error responses, that is, vowels heard instead of the intended vowels in more than five percent of instances.

Table 1. Mean rate at which three American listeners (A1–A3) identified correctly the vowels in six English words as spoken by native speakers of British English (n = 8) and Dutch (n = 50). The numbers indicate the percentage of times each vowel was identified correctly. The phonetic symbols in parentheses indicate the vowels heard instead of the intended vowel in more than 5 % of instances; their ordering indicates relative frequency of occurrence. The Dutch talkers may have intended to produce the word *hot* with a British English variant rather than an American English variant (i.e. /ɒ/ rather than /ɑ/). It is assumed that when the AE listeners used the keyword *hot* they heard /ɑ/.

British English Talkers

	heat /i/	*hit* /ɪ/	*hoot* /u/	*hot* /ɒ/	*hat* /æ/	*hut* /ʌ/	*mean*
A1	99	99	100	96	86 (ʌ, ɛ)	99	97
A2	99	100	96	99	82 (ʌ)	64 (ɑ)	90
A3	99	100	98	98	88 (aʊ)	81 (ɑ, ɛ)	94
mean	99	100	98	98	85 (ʌ)	81 (ɑ)	94

Dutch Talkers

	heat /i/	*hit* /ɪ/	*hoot* /u/	*hot* /ɒ/	*hat* /æ/	*hut* /ʌ/	*mean*
A1	99	100	84 (ʊ)	82 (ʌ)	63 (ɛ, ʌ)	87 (ɑ)	86
A2	100	100	97	88 (ʌ)	69 (ʌ, ɛ)	75 (ɑ)	88
A3	98	100	81 (ʊ)	80 (ʌ)	69 (ɛ, ʌ)	79 (ɑ, æ)	85
mean	99	100	87 (ʊ)	83 (ʌ)	69 (ʌ, ɛ)	80 (ɑ)	86

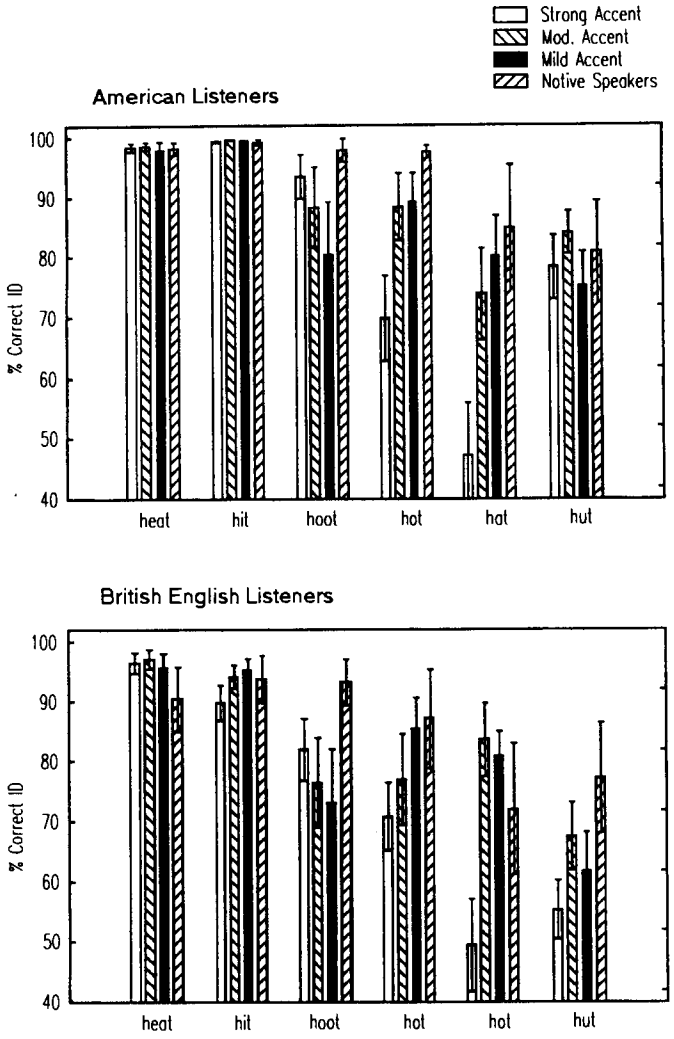

Figure 3. Upper panel: mean rate at which American English listeners correctly identified six English vowels (/i/, /I/, /u/, /ɒ/, /æ/, /ʌ/) spoken by Dutch talkers who spoke English with relatively strong, moderate, or mild foreign accents (16 per group), and by native speakers of British English (n = 8); Lower panel: results obtained for three British English listeners. The error bars bracket +/– one standard error.

Figure 3 (top) shows the mean percentage correct scores for vowels spoken by the native speakers and the Dutch subgroups formed on the basis of foreign accent scores. The data shown here were averaged over the three AE listeners, who varied somewhat in their overall rate of correct identifications. Averaged across all six vowels, the correct identification rate was greater for native than nonnative talkers (94% versus 86%). Four vowels (/i/, /I/, /u/, /ɒ/) produced by the native BE talkers were identified at near-perfect rates, but two of their other vowels (/æ/, /ʌ/) were identified in less than 90% of instances. (Note: the symbols /ɒ/ and /ɑ/ are used interchangeably here for the vowel in *hot*. It is uncertain whether the Dutch talkers intended to produce the BE variant (/ɒ/) or the AE variant (/ɑ/) when saying this word. We assume that when American listeners identified a vowel using the keyword *hot* they heard /ɑ/, whereas the BE listeners heard /ɒ/.)

The native BE talkers' /æ/s tended to be misidentified as /ʌ/ by the AE listeners; and their /ʌ/s tended to be misidentified as /ɑ/. The relatively poor intelligibility of /æ/ and /ʌ/ as spoken by the BE talkers agrees with results obtained previously for AE talkers' production of these vowels (see Flege 1990b, Table 1). However, the AE listeners identified the vowel in *hot*, which is implemented as /ɒ/ in British English, somewhat better than the vowel that Americans produce in this word (viz. /ɑ/).

As for the native BE speakers, the Dutch talkers' /i/s and /I/s were also identified at near-perfect rates and their /æ/s and /ʌ/s were identified relatively poorly. The greatest difference between the native and Dutch talkers was for /u/ and /ɑ/. The Dutch talkers' vowels were less intelligible than the native talkers' because their /u/ was heard as /U/ and their /ɑ/ (/ɒ/) as /ʌ/. Other common substitutions heard in the Dutch-accented English were /ʌ/-for-/æ/, /ɛ/-for-/æ/, and /ɑ/-for-/ʌ/. The only important difference in substitution errors heard for the native and Dutch talkers was that the Dutch talkers' /æ/ attempts were sometimes heard as /ɛ/. The /ɛ/ variants were likely to have been the result of cross-language transfer, for /ɛ/ seems to be the Dutch vowel closest to English /æ/.

Figure 3 (top) shows that there were systematic differences between the three Dutch groups for certain vowels but not others. Between-group differences did not exist for either /i/ or /I/ because these vowels were identified consistently at near-perfect rates. The rate of intelligibility for /ʌ/ was about 80% correct for all three Dutch groups. The percent correct scores for /ɒ/ and /æ/ increased as a function of how well the Dutch talkers spoke English. For /ɒ/ (/ɑ/), the Dutch talkers with strong, moderate, and mild foreign accents had percent correct scores of 70%, 87%, and 90%, respectively. For /æ/, the percent correct scores were 47%, 74%, and 80%. Conversely, the

scores for /u/ seemed to *decrease* as a function of how well the Dutch subjects pronounced English. The percent scores for the Dutch talkers with relatively strong, moderate, and mild accents were 94%, 87%, and 81%, respectively.

The percent correct scores obtained for the AE listeners were submitted to a mixed-design ANOVA to determine if any of the Dutch subgroups differed from the native BE talkers. The ANOVA yielded a significant Group × Vowel interaction [$F(15,260) = 2.64$, $p < 0.001$]. Tests of simple main effects suggested that learning had taken place for two of the English six vowels. The Group effect was significant for /ɒ/ [$F(3,52) = 4.09$, $p < 0.011$] and /æ/ [$F(3,52) = 4.48$, $p = 0.007$] but it was nonsignificant for the other four vowels ($p > 0.10$). Post-hoc tests (Newman-Keuls, alpha = 0.05) revealed that the Dutch talkers with moderate and mild foreign accents had higher correct identification rates for /æ/and /ɒ/ than strongly accented Dutch talkers, but they did not differ from the native BE talkers. The results for the new vowel /æ/ were predicted by the SLM, but not the results for the similar vowel /ɒ/.[18]

6.2 British English listeners

The misidentifications of vowels by the three British listeners are summarized in Table 2. The mean rate at which the BE listeners identified vowels spoken by native BE talkers and talkers in the three Dutch groups is shown in Figure 3 (bottom).

The BE listeners were expected to be better able than the AE listeners to identify vowels spoken by their fellow countrymen, but the rate of correct identifications of vowels spoken by BE talkers, was actually lower for BE than AE listeners (86% versus 94% correct). This paradoxical finding may be the result of a methodological difference. Recall that the BE but not the AE listeners were unaware that the talkers had actually intended to produce just *six* vowels, not all 14 vowels shown on the response box. In support of this, Table 2 shows that the BE listeners used a wider range of response variants in identifying vowels than did the AE listeners. One response variant used by the BE but not the AE listeners in identifying /ɒ/ (/ɑ/) was /ʌ/. In addition to hearing /ʌ/-for-/æ/ substitutions, the BE listeners also heard /ɛ/-for-/æ/ substitutions. And in addition to hearing /ɒ/ (/ɑ/)-for-/ʌ/, the BE listeners also heard /æ/ for /ʌ/. Importantly, the misidentifications of the native BE and AE listeners were generally similar. The BE listeners misheard /æ/ as /ʌ/. They heard /ʌ/ as either /ɒ/ or /æ/, /u/ as /U/, and /ɒ/ as /ʌ/.

Table 2. Mean rate of correct identifications for British English listeners B1–B3. The numbers indicate the percentage of times these listeners identified correctly the vowels in six English words as spoken by native speakers of British English (n = 8) and Dutch (n = 50). (See Table 1 legend.)

British English Talkers

	heat /i/	*hit* /I/	*hoot* /u/	*hot* /ɒ/	*hat* /æ/	*hut* /ʌ/	*mean*
B1	85	82 (eᴵ, er)	82 (ʊ, o)	82 (ʌ)	86 (aʊ)	76 (aʊ, æ)	82
B2	95	100	99	96	57 (ʌ, ɛ)	85 (ɑ)	89
B3	93	100	100	85 (ʌ)	75 (ɛ, aʊ)	72 (ɑ, æ)	88
mean	91	94	94	88 (ʌ)	73 (ʌ, ɛ, aʊ)	78 (ɑ, æ, aʊ)	86

Dutch Talkers

	heat /i/	*hit* /I/	*hoot* /u/	*hot* /ɒ/	*hat* /æ/	*hut* /ʌ/	*mean*
B1	94	83 (eᴵ)	66 (ʊ, o)	73 (aʊ, ʌ)	80 (aʊ, ʌ)	55 (aʊ, æ)	86
B2	99	96	82 (ʊ, o)	78 (ʌ)	60 (ɛ, ʌ)	71 (ɒ, ʊ, æ)	88
B3	97	100	85 (ʊ)	86 (ʌ)	76 (ɛ, ʌ)	62 (æ, ɒ)	85
mean	97	93	78 (ʊ, o)	79 (ʌ)	72 (ʌ, ɛ)	63 (æ, aʊ, ɒ)	86

It came as no surprise, given the difference in the number of response categories between the two listener groups, that the BE listeners also identified fewer vowels spoken by the Dutch talkers than did the AE listeners (80% vs 86%). As shown in Figure 3 (bottom), they identified the Dutch talkers' attempts at /i/ and /I/ most of the time (97% and 93% correct, respectively). The BE listeners identified the Dutch talkers' /u/s and /ɒ/s less often (78%, 79%) than the Dutch talkers' high front vowels, and identified their /æ/ and /ʌ/ even more poorly (72%, 63% correct).

Between-group differences in intelligibility existed for all six vowels. Somewhat surprisingly, the /i/s produced by the Dutch subjects in all three groups were more intelligible than were the native BE talkers' /i/s. There was a small increase in the rate of correct /I/ identifications as a function of accent. The rates for Dutch subjects with strong, moderate, and mild accent were 90%, 94%, and 96%, respectively. A similar pattern was evident for /ɒ/ (72%, 78%, and 86%), /æ/ (50%, 84%, 82%) and /ʌ/ (56%, 68%, 65%). For /u/, on the other hand, performance seemed to *deteriorate* slightly along with improvements in accent (82%, 77%, 74%).

As expected, the ANOVA yielded a significant Group × Vowel interaction [$F(15,260) = 2.34$, $p = 0.004$]. The simple main effect of Group was significant for /æ/ [$F(3,52) = 6.42$, $p < 0.001$] but nonsignificant for all other vowels including /ɒ/. Post-hoc tests revealed that the Dutch talkers with moderate and mild foreign accents had higher scores for /æ/ than those with strong accents ($p < 0.05$). The moderately and mildly-accented Dutch talkers did not differ significantly from the native BE talkers. These results supported the prediction of the SLM for /æ/. It is notable that, for the BE listeners, the Dutch subjects did *not* show a significant improvement in /ɒ/ intelligibility.

The variants that the BE and AE listeners gave in identifying the vowel in *hot* as spoken by mildly and strongly-accented Dutch talkers were tabulated in the hopes of deriving insight into why the AE listeners but not the BE listeners registered a significant improvement for /ɒ/ (which was classified as a similar vowel). The AE listeners used fewer error variants, and applied those variants to fewer Dutch talkers in the Mild than Strong Foreign Accent group.[19] Unlike the AE listeners, the BE listeners did not give fewer error variants for talkers in the Mild than Strong Foreign Accent groups, but they did show a decrease in the number of talkers to whom they applied the error variants that were used.

6.3 Individual talkers' production of the new vowel /æ/.

The SLM generates the prediction that Late L2 Learners will produce a new L2 vowel authentically once they recognize it to be new. Figure 4 was prepared to show the correct identification rates for the /æ/s spoken by 48 individual Dutch talkers because little is known at present concerning *how long* such recognition may take.

Figure 4 (top) shows the rates obtained from the AE listeners; and Figure 4 (bottom) shows the rates obtained for the native BE listeners. Some talkers in all three Dutch subgroups produced the new vowel /æ/ well whereas others produced it poorly. The AE listeners seldom identified one native BE talker's /æ/s correctly, frequently hearing /aᵁ/ or /ʌ/.[20] The range of correct identifications for the remaining BE talkers was 78%–100% correct. All three subgroups of Dutch talkers showed a wide range for /æ/. Just three of the 16 strongly-accented Dutch talkers had intelligibility rates greater than 75% correct. Eleven moderately-accented and 12 mildly-accented Dutch talkers exceeded this rate.

The range of percent correct scores for the native BE talkers was greater for the BE than AE listeners. The one native BE talker whose /æ/ was poorly

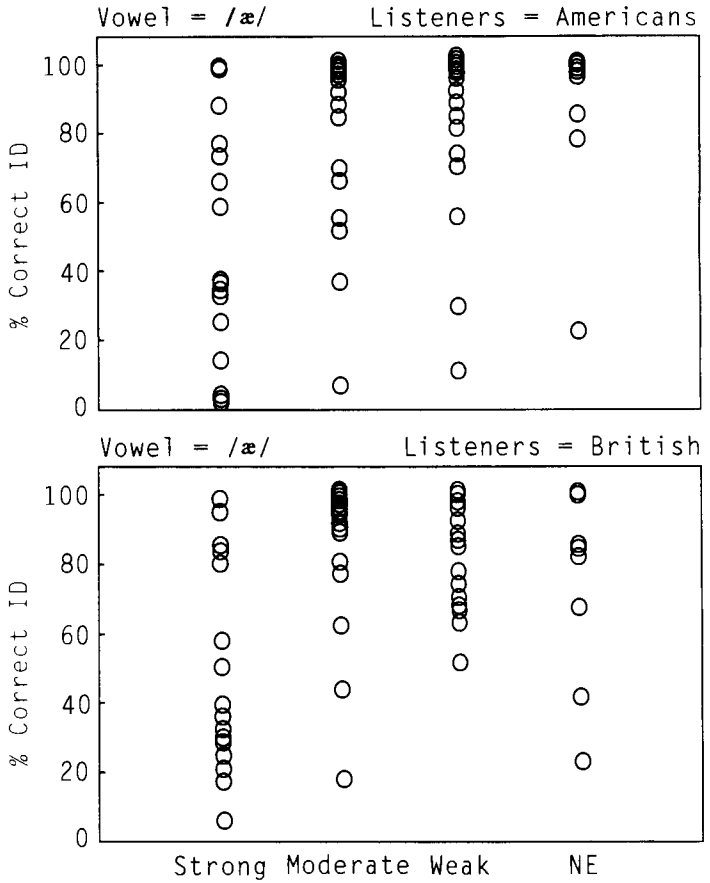

Figure 4. Mean rate of correct identifications of /æ/ as spoken by native Dutch talkers with strong, moderate, or mild foreign accents (n = 16 per group), and by eight native speakers of British English (n = 8). The top panel shows results obtained from native American English listeners; the bottom panel shows results obtained for British English listeners. Each data point is based on 27 judgements (3 tokens × 3 presentations × 3 listeners).

identified by the AE listeners was also poorly identified by the BE listeners (22% correct for both listener groups). However, several talkers' /æ/s were identified less often by the BE than the AE listeners. One talker's identification rate for /æ/ dropped from 100% to 40% correct because the BE listeners heard his /æ/ attempts as /ɛ/; another talker's /æ/ rate dropped from 96% to 67% because the BE listeners heard /ʌ/.

7.0 Acoustic analyses

The intelligibility study supported the SLM's prediction that the new vowel /æ/ would be produced authentically by at least the most proficient Dutch speakers of English, but it provided little support for the model's prediction concerning English vowels classified as "similar" (viz. (/i/, /u/, /ʌ/, /ɒ/).

Given the prediction that even highly proficient Dutch speakers of English would produce similar vowels in a Dutch-like manner, it was expected that the similar English vowels produced by all three Dutch subjects would be less intelligible than those spoken by native BE talkers. This prediction was not supported, however. The possibility exists that persistent difference between native and non-native speakers did exist for the similar vowels, as predicted, but that the intelligibility measure did not have sufficient resolution to reveal the difference. After all, intelligibility scores are based on the percentage of correct identifications. *Identification* implies the reduction – or elimination – of fine-grained stimulus characteristics. An acoustic analysis was therefore carried out to further test the prediction of the SLM concerning vowels.

A 14-coefficient Linear Predictive Coding (LPC) model was used to estimate the center frequency of the first two formants in vowels spoken by the 10 Dutch males with the best accents and the 10 Dutch males with the poorest accents. For the LPC analysis, a 25.6-ms Hamming window was placed at the acoustic midpoint of the vowels in *heat, hit, hat, hot, hut*, and *hoot*. To provide enough BE talkers to permit a statistical comparison between native and Dutch talkers, the data reported by Holtse (1972) for six male native speakers of standard RP were added to data obtained here for four BE males.[21]

7.1 Results and discussion

The mean values (in Hz) for the four subject groups presented in Table 3 have been plotted in Mels in Figure 5. This figure shows that the Dutch subjects with a relatively good English pronunciation more closely approximated the native BE talkers' vowel system than the Dutch subjects with relatively poor accents. Most of the differences between the native and Dutch speaker, and those between the two Dutch groups, were confined to the new vowel /æ/ and the similar vowels /ʌ/ and /ɒ/ (/ʊ/). There seemed to be little difference between the two similar vowels /i/ and /u/.

Table 3. Mean first and second formant frequencies (in Hz) for six English vowels spoken by 10 male native speakers of British English (4 from the present study and 6 from a study by Holtse, 1972), 10 native Dutch males with good accents in English, and 10 native Dutch males with relatively poor (i.e., 'strong') accents in English.

Native Speakers of English

	/i/	/ɪ/	/æ/	/ʌ/	/ɒ/	/ʊ/
F_1	270 (56)	405 (43)	715 (93)	681 (85)	649 (103)	294 (40)
F_2	2410 (74)	2033 (141)	1644 (178)	1294 (101)	1021 (113)	1232 (236)

Dutch Subjects – good Accents

	/i/	/ɪ/	/æ/	/ʌ/	/ɒ/	/ʊ/
F_1	283 (29)	390 (21)	638 (85)	572 (89)	526 (50)	336 (27)
F_2	2255 (186)	1895 (129)	1482 (96)	1217 (57)	921 (85)	1102 (94)

Dutch Subjects – poor Accents

	/i/	/ɪ/	/æ/	/ʌ/	/ɒ/	/ʊ/
F_1	281 (33)	389 (33)	604 (186)	531 (125)	516 (83)	324 (20)
F_2	2215 227)	1885 (132)	1615 (131)	1296 (91)	1018 (120)	1078 (162)

The 30 mean F_1 and F_2 values (3 groups × 10 subjects) for each of the six vowels were submitted to separate ANOVAs to determine if any of these differences were significant.[22] The difference between groups was nonsignificant for the new vowel /æ/. As expected from Disner's (1083) cross-language research, the between-group differences for the identical vowel /ɪ/ was nonsignificant. It is noteworthy, however, that the differences for this vowel was about the same as those for the similar vowels /i/ and /u/.

As predicted by the SLM, a between-group difference was obtained for the F_1 values in the similar vowels /ʌ/ and /ɒ/ [$F(2,27) = 5.86, 8.24$]. Newman-Keuls post-hoc tests revealed that the native BE talkers' frequencies were significantly higher than those of both Dutch groups. The differences for the other two similar vowels (/i/, /u/) were nonsignificant, however, as were all of the between-group differences for F_2.

The acoustic results partially confirmed the SLM's prediction that similar vowels represent a persistent pronunciation problem for adults who learn an L2. One reason why between-group differences were not seen for two of the

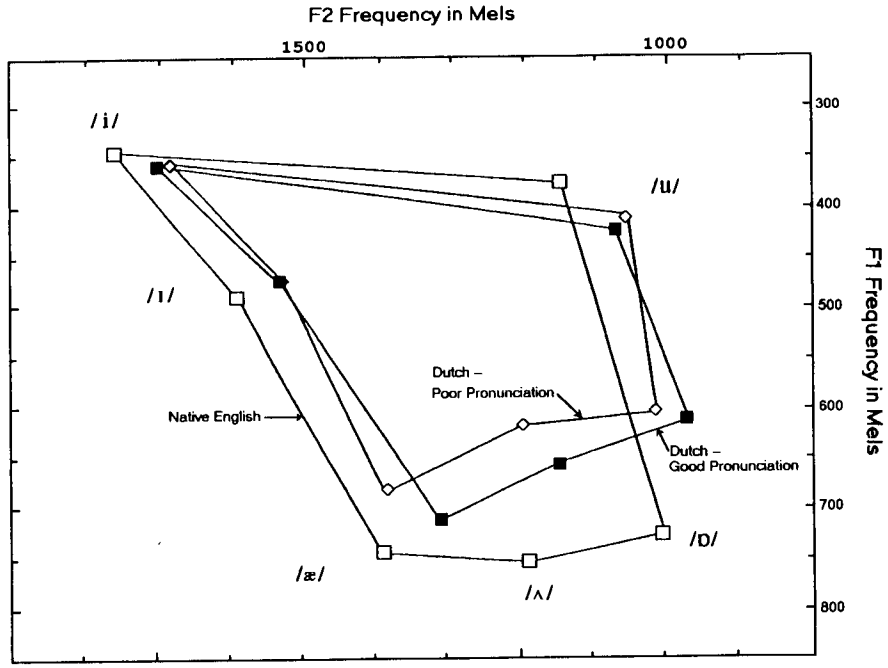

Figure 5. Mean F_1 and F_2 frequencies (in Mels) in six English vowels spoken by native speakers of English and Dutch subjects differing in degree of foreign accent (see Table 3 legend).

four similar vowels may have been that the differences between the two similar English vowels and their counterparts in Dutch were too small to detect.

8.0 General discussion

This study tested a second-language Speech Learning Model (SLM) by examining formant frequencies and the perceptual intelligibility of identical, similar, and new English vowels spoken by native speakers of British English (BE) and native speakers of Dutch. The Dutch talkers were differentiated according to their degree of global foreign accent in English.

As expected from previous vowel intelligibility studies (see Flege, 1992, Table 1), high vowels (/i/, /ɪ/, /u/) were identified correctly more often than non-high vowels (/ɑ/, /æ/, /ʌ/). The between-vowel differences were not significant for the native BE talkers, however, either when the native speakers'

vowels were auditorily assessed by fellow native speakers of British English (BE) or by native speakers of American English (AE). It came as no surprise that English /i/ was as intelligible when spoken by talkers in all three Dutch subgroups as when spoken by the native BE talkers. This vowel was classified as "identical" to the /ɪ/ of Dutch because previous research had shown little or no difference between the /ɪ/ of Dutch and that of English. No difference between the three groups was evident.

8.1 The production of new vowels

An important difference between the Dutch talkers with mild, moderate and strong foreign accents existed for the new vowel /æ/, however. The SLM predicted that in early stages of learning Late L2 learners may initially fail to produce new L2 sounds authentically, but may eventually do so as a result of establishing phonetic categories.

In support of this, the Dutch talkers with moderate and mild foreign accents produced /æ/ more intelligibly than did the Dutch talkers with strong foreign accents. The intelligibility of /æ/s spoken by the moderately and mildly-accented Dutch talkers did not differ significantly from that of the native BE talkers. The /æ/s of the Dutch talkers with strong accents were significantly less intelligible than their /ɪ/s, /i/s, or /u/s, whereas the intelligibility of the /æ/s produced by the Dutch talkers with moderate and mild foreign accents did not differ from that for high vowels. The result for /æ/ agrees with the finding by Bohn and Flege (1992) that Germans are able to learn English /æ/. Taken together with that finding, the results presented here show that phonetic learning remains possible beyond early childhood. The results support an important prediction of the SLM, namely that L2 vowels occupying a portion of the phonetic space not exploited by the L1 vowel system can be produced authentically by Late L2 learners.

There are several reasons for caution in accepting this conclusion, however. One might argue that /æ/ isn't really a new vowel because Dutch has English loanwords with /æ/ (e.g. *fan, dancing*). The vowels in these words may be realized with a slightly lower quality than the Dutch /ɛ/ according to James (1989, personal communication). The Dutch talkers who succeeded in producing /æ/ authentically were Late L2 learners who had first begun learning English in school at the age of 12 years, so one might argue that they had not yet passed a sensitive period for speech learning.[23] One additional reason for caution is that the Dutch subjects who succeeded in producing /æ/s authentically were all students majoring in English at the University of

Utrecht. If they succeeded because of some special training or talent, the results may not generalize to other subjects who are equally experienced in English L2.

It is important to note that many of the Dutch subjects examined here produced English /æ/s that were identified in 100% of instances by both AE and British English (BE) listeners. However, contrary to the SLM's prediction, some talkers in all three Dutch subgroups produced /æ/ poorly. This leads one to ask "Why did some Dutch subjects but not others succeed in learning /æ/?" This finding, along with comparable findings from other acoustic studies completed recently in our laboratory, suggests that adult L2 learners do not proceed inevitably towards successful production of new vowels. Additional research will be needed to ascertain the basis for the striking differences between individuals observed here.

8.2 The production of similar vowels

An hypothesis of the SLM is that category formation for similar L2 sounds is blocked by equivalence classification. This led to the prediction that Late L2 learners will phonetically approximate the phonetic norm for similar L2 vowels but will never produce them authentically. In agreement with this, there was not a significant difference in intelligibility between the Dutch talkers with strong, moderate, and mild foreign accents for three of the similar L2 vowels examined (/i/, /u/, and /ʌ/).

However, contrary to hypothesis, the Dutch groups did not differ from native speakers of English; and improvement with L2 experience was noted for the similar vowel /ɒ/ (American English /ɑ/). Intelligibility for /ɒ/ was higher for the moderately-and mildly-accented Dutch talkers than for the strongly-accented Dutch talkers. One might argue that the improvement for /ɒ/ did not provide counterevidence to the SLM's prediction about similar vowels because /ɒ/ is used to produce words like *hot* in British English whereas /ɑ/ is the most common vowel used in American English. An improvement in Dutch talker's /ɒ/ production was noted in the intelligibility data obtained from British but not from American English listeners.

The lack of a difference between the Dutch and native speakers for the similar L2 vowels represents a more serious challenge to the model. The SLM hypothesizes that similar L2 vowels pose a persistent problem for Late L2 learners because they continue to be identified with vowels in the L1 as the result of equivalence classification. This led to the prediction that similar English vowels spoken by Dutch subjects (even those with very good overall

accents) would differ from those produced by native speakers of English. More specifically, it was predicted that the Dutch talkers would show "compromise" acoustic values representing an assimilation of the phonetic properties of the corresponding L1 and L2 sounds that were equated.

The present study failed to show a significant difference in intelligibility between native and Dutch talkers for any of the similar vowels examined, but an acoustic analysis supported partially the prediction concerning similar vowels. It revealed significant formant frequency differences in the production of the similar vowels /ɒ/ and /ʌ/ between native speakers and Dutch subjects, both those with good and relatively poor accents. These two English vowels were probably more distant from their closest Dutch counterparts than the other two similar English vowels that did not yield a native vs nonnative difference (viz. /i/, /u/). It is worth noting, however, that even if the predicted difference between the native and nonnative speakers' /i/s and /u/s existed, acoustic measurement resolution may have been insufficient to show it. This is because the English /i/ and /u/ may be so close to their Dutch counterparts that even the unmodified substitution of a Dutch vowel for the similar L2 vowel would not reduce intelligibility, or be observable acoustically.

The possibility exists that a more fine-grained auditory analysis, such as the paired comparison of Dutch and English /i/s (see Flege 1984), would support the prediction of a continued difference between native and nonnative speakers for the similar L2 vowels. Whatever the outcome of such a test, it is clear that the larger the acoustic difference between similar vowels in L1 and L2, the easier they are to measure acoustically (and probably to detect auditorily). Thus the results suggest an important methodological limitation that may impede research testing the hypothesized difference between identical and similar vowels (see Bohn–Flege 1990).

Another factor must also be considered. Major (1987) presented evidence suggesting that when native Portuguese learners of English added an /æ/ category, it may have affected their production of the similar vowel /ɛ/ as the result of system pressure. L2 learners' approximation of similar L2 vowels cannot be considered in isolation. To provide optimal insight, vowel *systems* rather than isolated vowels must be examined.

System pressure may have been involved in a trend seen for both the BE and AE listeners. The present study showed that percent correct scores for /u/ decreased nonsignificantly as foreign accents improved. Perhaps the addition of an /U/ category (which was not examined) precipitated a shift in /u/ pronunciation. Alternatively, Collins and Mees (1984) noted that the production of English /u/ deteriorates as Dutch speakers gain experience in English because experienced Dutch speakers of English begin to substitute

/yu/ for English /u/. Perhaps the Dutch talkers with the best English pronunciations had noted, and begun reproducing, the very fronted, [y]-like realizations of /u/ used by native speakers of BE (Bauer 1985). If so, the vowel of *boot* may have been misidentified by native BE and AE listeners when presented in isolation.

This chapter has provided a more explicit operational definition of the distinction between similar and new vowels than has been offered previously (see also Flege 1992). However, important questions remain to be answered, such as "How much must an L2 vowel differ from vowels in the L1 to be regarded as new?" It remains to be determined if there is a phonetic difference threshold that, once crossed, triggers the formation of a new phonetic category. Further research may show that the new versus similar vowel distinction, just like the identical versus similar distinction, can be defined only on the basis of an individual learner's vowel system, and perhaps on the basis of undefined individual modes of phonetic processing.

8.3 Conclusions

The perceptual and acoustic analyses presented in this chapter provided partial support for predictions derived from Flege's (1988b, 1992) Speech Learning Model. The SLM represents an important departure from most previous approaches to L2 speech learning in that it assumes a continuity in the mechanisms used to acquire the L1 and to learn an L2 later in life. The SLM posits that speech learning does not end when the L1 has been "mastered". Humans continue to learn phonetically whenever they are required to communicate via a phonetic system that differs systematically from the one(s) they have previously used. The SLM leads to the prediction that the phonetic system of individuals who learn an L2 will evolve even if the L2 is learned in adulthood.[24]

The most dramatic changes, it is predicted, will result from the addition of phonetic categories for new L2 sounds that occupy a portion of the phonetic space that has not been exploited previously. Other changes may result from the updating of existing phonetic categories so that they will better reflect the acoustic substance of the wide array of similar phones in L1 and L2. The establishment of new phonetic categories require the establishment of new implementation rules if they are to be seen in speech production. The relatively minor perceptual changes that result from experience with similar sounds may lead to changes in phonetic realization rules.

The rate and extent of the perceptual changes just noted may differ importantly between individuals; and individuals may differ in terms of how successful they are in the motoric learning needed to realize the perceptual changes. Future work is needed to clarify the basis for individual subject differences. This work will need to fully consider the relative phonetic distance of sounds in the L2 from sounds in the L1.

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Notes

1. I recognize, of course, that there are instances in which an L2 learner recognizes the existence of a phonetic contrast in the L2 but is unable to produce it reliably. Work in our laboratory has documented the slow development of speech production skills in both children acquiring an L1 and adults learning an L2 (see e.g. Flege–Davidian 1985; Flege 1988c).
2. However, for consonants at least, positive transfer may not extend to new syllable positions. Recent research has shown that Chinese subjects have difficulty producing and perceiving a contrast between /t/ and /d/ in the final position of English words even though an English-like /t/–/d/ contrast occurs in the initial position of their L1 (Flege–Davidian 1985; Flege et al. 1987; Flege 1988c).
3. For example, Flege (1987a) examined formant frequency values in French /i/ and English /i/, and also between the /u/s of French and English. Significant acoustic differences were obtained for both pairs of French-English vowels; and native English listeners were able to identify French vowels at significantly above-chance rates when asked to determine which member of a vowel pair had been spoken by a native French speaker. Both the acoustic and perceptual tests conformed to traditional phonetic descriptions of French /i/ and /u/ being more "peripheral" than their English counterparts.
4. The difference in symbols leads to different expectations concerning L2 learning. For example, symbolizing the lax vowel as /I/ suggests that it will be regarded as a new vowel by Spanish learners of English whereas symbolizing it as a short /i/ suggests that is will be regarded as a *similar* vowel.
5. Elsendoorn (1986) offered the same view. Data reported by Schouten (1975) support the belief that L2 learners may not recognize immediately the identity of L1 and L2 vowels. In that study, 77 native Dutch students majoring in English at the

University of Utrecht identified synthetic vowels with a fixed 175-ms duration using 15 phonetic symbols and keywords. The synthetic English /I/s were identified correctly in only 71% of instances, probably because of difficulty using phonetic symbols, or because the fixed duration was more appropriate for Dutch /e/ than /I/ (van Heuven 1986). The /I/s were misidentified as /eᴵ/ in 13% of instances and as /ʌ/ in 12% of instances.

6. It should be noted, however, that a great deal of variation exists in the production of BE /ʌ/ (Collins–Mees 1984). Barry (1974) indicated that there are two distinct "norms" for /ʌ/, one for RP English and another, more centralized regional English variant. This observation was later confirmed by a study comparing acoustic values obtained in a number of studies examining English /ʌ/ (Bauer 1985).
7. Holtse (1972, p. 9) noted the presence of additional low amplitude formants in BE /ʌ/ which, although not classified as F_1 or F_2, might cause this vowel to be perceived as "closer in quality" than might be suggested by its position in an F_1–F_2 space. According to Elsendoorn (1986), BE /ʌ/ is perceptually close to the Dutch schwa but would probably not be identified with it because the Dutch schwa occurs only in unstressed syllables.
8. Collins and Mees (1984) report that Dutch /ɔ/ differs perceptually as well as acoustically from BE /ɒ/. They indicate that native speakers of BE identify Dutch /ɑ/ with BE /ɒ/.
9. Danchev's (1986) observations were based on several sources of data which included spelling errors and loanword phonology as well as actual pronunciations by L2 learners. The L2 learners were high school and university students and individuals enrolled in intensive English classes who may not have fulfilled the condition of "sufficient native-speaker input". English-learning children must receive several years of input before they succeed in producing /æ/ correctly (Amastae 1978; Mack and Lieberman 1985), so there is no reason to expect Bulgarian adults to do so on the basis of less input.
10. Portuguese does not have a phoneme whose most characteristic allophone is [æ]. Portuguese has an /e/ and /ɛ/. Acoustic data (Godinez 1978) suggests that Portuguese /ɛ/ is produced with a wide range of variants. It overlaps the Portuguese /e/ category in an F_1-F_2 space. Portuguese /ɛ/ seems to occupy a portion of the acoustic space occupied by English /æ/, but an even larger portion of the space occupied by English /ɛ/.
11. The finding just reported is based on my own analysis of perceptual data reported by Major (1987), which were obtained at the Biocommunication Research Laboratory in Birmingham, Alabama.
12. The number of response categories is just one of many factors that may influence how well vowels are identified in an identification experiment. See Flege (1990b) for a discussion.
13. For details concerning the subjects, see Flege (1992).
14. Removing the /h/ noise and the stop gap and release burst for the final /t/ was considered preferable to having the talkers try to produce *isolated* vowels. This is because English lax vowels are not permitted to occur in open syllables. Moreover, isolated vowels often have offglides not seen in CVCs.
15. The listeners always produced the keywords with the expected vowel (e.g., *hoit* was read as [hoᴵt]) when asked to read them.

16. One BE listener was unable to pass the pretest and was replaced; another British listener passed the pretest but was unable to complete the experiment, and so was also replaced.
17. In Dutch, /t/ is implemented as a voiceless unaspirated stop with short-lag VOT values. Flege and Eefting (1987a) found that the 50 Dutch talkers' foreign accent scores correlated positively with the VOT measured in their productions of English /t/. Thus the better was their overall pronunciation of English, the more closely the Dutch students approximated the phonetic norm of English for /t/. Moreover, a language background questionnaire revealed that the engineering students, who were all rated as having relatively strong accents, had less access to native speakers of English, and spoke English far less frequently than did the students majoring in English.
18. The effect of Vowel was nonsignificant for the native BE speakers [$F(5,35)$ = 2.41, p = 0.056], who seem to have been equally successful in producing all six vowels. The effect of Vowel was significant, however, for the Dutch talkers with strong, moderate, and mild accents [$F(5,35)$ = 15.7, 4.16, 4.07; $p < 0.01$]. Post-hoc tests showed that for the Mild Accent group, /ʌ/ was less intelligible than /i/ and /I/. For the Moderate Accent group, /ɒ/ but not /ʌ/ was less intelligible than /i/ and /I/. For the Strong Accent group, both /ʌ/ and /ɒ/ were less intelligible than /i/ and /I/. In addition, /ʌ/ and /ɒ/ were less intelligible than /u/; and /æ/ was less intelligible than all other vowels.
19. For the AE listeners, the number of talkers showing the following variants for the Mild Accent group were: /ʌ/ 3 talkers; /o/ 2 talkers; /U/ 1 talker. In the Strong Accent group it was: /ʌ/ 8; /o/ 3; /U/ 1; /æ/ 1. For the BE listeners the number of talkers in the Mild Accent group was: /ʌ/ 4; /aᵁ/ 3; /o/ 1; /æ/ 1; /U/ 1. And in the Strong Accent group it was: /ʌ/ 8; /aᵁ/ 6; /o/ 4; /æ/ 1; /U/ 1. There was not a significant difference in the rate at which the six vowels spoken by the native BE talkers were identified [$F(5,35)$ = 2.43, $p > 0.10$], but a Vowel main effect was obtained for the Dutch talkers with mild, moderate and strong accents [$F(5,35)$ = 7.68, 4.24 17.7, $p < 0.01$]. For the mildly-accented talkers, /ʌ/ was identified less often than /i/ and /I/, their /ʌ/s were identified less often than /ɒ/ or /æ/, and their /u/s less often than the /i/ or /I/. For the moderately-accented talkers, /ʌ/ was identified less often than /i/ and /I/. For the Dutch talkers with strong accents, both /ʌ/ and /æ/ were identified less well than /i/, /I/, /u/ and /ɒ/; and /ɒ/ was identified less often than /i/ or /I/.
20. This talker was a 25-year-old male from Preston, England living in Amsterdam. According to James (1989), this individual had been exposed to some "northwest regional influence (i.e., Lancashire)" which might be expected to have caused a backing and/or lowering of his /æ/.
21. Holtse measured formants in the vowels found in *heat-heed, hit-hid, hat-had, cut-cud, heart-hard,* and *coot-cooed* as spoken by six male native speakers of RP, most students or faculty members of the University of Copenhagen. Holtse's (1972) study differed from the present one in several respects. Vowels were measures spectrographically rather than by LPC analysis; means were based on a larger numer of tokens (viz. 10–16); and some of the lexical items examined in the two studies differed. However, the data for the four BE males from this study did not appear to differ systematically from Holtse's six BE male subjects.

22. The alpha level was set at 0.008 to obtain a per-experiment error rate of 0.05 for the F_1 and F_2 tests.
23. However, data summarized by Flege (1987b) suggest that the offset of the sensitive period for human speech learning occurs long before the age of 12 years.
24. The 1990 version of the SLM which has been presented here has been revised as described in Flege (1995).

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Perpeption and production of a new vowel category by adult second language learners[1]

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1 Introduction

This paper addresses two questions in L2 speech research: can adults learn to produce and perceive a second language vowel category for which no counterpart exists in their native language? And, secondly, if such learning of an L2 vowel by adults can be observed, what is the relation between their production and perception of the new category?

The first question is of interest not just in L2 speech research, but in L2 research in general. The still influential critical period hypothesis states that adults cannot overcome biologically conditioned limits on the ability to learn (an) additional language(s) successfully. With respect to L2 speech learning, this hypothesis would predict that adults will not establish phonetic categories for sounds which are not found in their L2. This view has recently been challenged by Flege (1987), who showed that adults can produce foreign vowels authentically if these vowels are unlike any native vowel, and if as learners they have had extensive exposure to the foreign language. Flege hypothesized that vowels which are sufficiently different from native vowels (like, in his study, French /y/ for native English speakers) will not be treated as equivalent to existing phonetic categories by L2 learners, and that sufficient input will enable adult learners to establish phonetic categories for new vowels.

The present study further tested the hypothesis that adult learners will eventually establish new phonetic categories for vowels that do not have an easily identifiable counterpart in the native language. It differs from previous studies of second language speech in that it considers both the perception and the production of a new vowel category by two groups of non-native speakers who differed in L2 experience. This made it possible to study the effect of L2 experience on category formation for new vowels, and to study the relation between perception and production in the acquisition of a new vowel category.

The results to be presented were obtained in a larger study which investigated the perception and the production of several English vowels, including