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The Identification of English Consonants by Native Speakers of Italian

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Abstract

This study examined the identification of English consonants in noise by native speakers of Italian. The effect of age of first exposure to English was evaluated by comparing three groups of subjects who continued to use Italian relatively often but differed according to their age of arrival (AOA) in Canada from Italy (early: 7, mid: 14, late: 19 years). The subjects in the late group made more errors identifying word-initial consonants than subjects in the early group did; however, the effect of AOA was nonsignificant for word-final stops. The effect of amount of native language (L1) use was evaluated by comparing two groups of early bilinguals who were matched for AOA (mean = 7 years) but differed according to self-reported percentage use of Italian (early: 32%, early-low: 8%). The early bilinguals who used Italian often (early) made significantly more errors identifying word-initial and word-final consonants than native English (NE) subjects did, whereas the early bilinguals who used Italian seldom (early-low) did not differ from the NE subjects. The subjects' phonological short-term memory was estimated by having them repeat Italian non-words. This was done in an attempt to identify the source of individual differences. The nonword repetition scores were in fact found to independently account for 15% of the variance in subjects' errors identifying word-final English consonants and 8% of the variance for word-initial consonants.

Introduction

The perceptual system developed for speech becomes attuned to the phonetic inventory of the native language (L1) during L1 acquisition. According to some [e.g. Best and Strange, 1992], the speech perception system remains somewhat malleable across the life span. This means that as learners of a second language (L2) gain experience with the L2 phonetic system, they will begin to perceive L2 vowels and consonants (or 'sounds', for short) more like monolingual native speakers of the L2. According to Sebastián-Gallés and Soto-Faraco [1999, p. 120], on the other hand, there are 'severe limitations to the malleability of the initially acquired L1 phonemic categories, even under conditions of early and extensive exposure'.

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The purpose of this article was to provide a better understanding of the extent to which the speech perception system remains malleable. We did this by examining the identification of English consonants by adult native speakers of Italian. Two criteria were used in selecting subjects for this study. One was the age at which the subjects began to learn English, which was indexed by their age of arrival (AOA) in Canada from Italy. The second criterion used in subject selection was amount of self-reported use of Italian. Two aims of the study were to determine if AOA and amount of L1 use would affect the native Italian subjects' accuracy in identifying English consonants. A third specific aim of the study was to determine if individual differences in phonological short-term memory (PSTM) would affect the subjects' identification of English consonants independently of AOA and L1 use.

Hypotheses

The first hypothesis tested here was that AOA would affect performance. This led to the prediction that the subjects who arrived in Canada as young adults would identify English consonants less accurately than would the subjects who arrived as children.

The AOA hypothesis was based on a number of previous findings. Previous research has shown that as native Italian subjects' AOAs to Canada increased, their foreign accents in English sentences became stronger [e.g. Flege et al., 1995a] and the accuracy with which they produced English vowels and consonants decreased [Flege et al., 1995b; Munro et al., 1996]. Adult learners of English in the US have been observed to differ from native English (NE) speakers in identifying English vowels and consonants [Flege et al., 1995c, 1996b, 1997a]. Typically, adults show only gradual progress in learning to perceive English sounds as their length of residence (LOR) in the US increases [Flege and Liu, 2000]. However, Yamada [1995] found that the earlier native speakers of Japanese arrived in the US the more accurately they identified synthetic tokens of English /ɹ/ and /l/[1], and Flege et al. [1999a] found that native Italian adults who began learning English as children discriminated English vowels as accurately as NE speakers did, whereas native Italian adults who began learning English in adulthood did so less accurately than NE speakers.

The second hypothesis tested here was that amount of L1 use would affect the native Italian subjects' identification of English consonants. This hypothesis was motivated by the results of studies examining overall degrees of foreign accent in sentences. Flege et al. [1995b] found that amount of English-language use by Italian-English bilinguals accounted for a significant amount of variance in foreign accent ratings independently of AOA. More recently, Flege et al. [1997b] assessed degree of foreign accent in groups of Italian-English bilinguals who were matched for AOA in Canada (mean = 7 years) but differed in self-reported use of Italian. Both groups of early bilinguals were found to have detectable foreign accents. However, the foreign accents of the subjects who used Italian relatively often were stronger than were the foreign

[1] However, as has been the case in previous studies, the AOA of the native Japanese subjects examined by Yamada [1995] was correlated with LOR in the United States. This made it difficult to determine whether or to what extent the observed effect of AOA was independent of LOR.

accents of the subjects who used Italian seldom. Guion et al. [1999] obtained similar results for early Quichua-Spanish and Korean-English bilinguals, and Piske and MacKay [1999] observed an effect of L1 use on degree of foreign accent in English sentences for late as well as early Italian-English bilinguals. One possible interpretation of these L1 use effects is that the more the L1 is used, the stronger the L1 system will remain and, thus, the stronger will be its influence on L2 production.

Very little is now known concerning the effect of L1 use, if any, on the perception of L2 phonetic segments. Flege et al. [1999a] examined the discrimination of English vowels by groups of early Italian-English bilinguals who were matched for AOA (mean = 7 years) but differed in Italian use (early-low: 8%, early: 32%). The two early bilingual groups did not differ significantly from one another in discriminating pairs of English vowels, nor did either group differ from a NE group. This finding diverges from the results obtained by Sebastián-Gallés and Soto-Faraco [1999], who used a modified gating task to examine the identification of Catalan vowels (/e/, /ɛ/, /o/, /ɔ/) and consonants (/s/, /z/, /ʃ/, /ʒ/). With the exception of /s/ and /z/, early Spanish-Catalan bilinguals needed to hear longer portions of the target sounds to correctly identify them than did a matched group of native Catalan subjects. The authors suggested that 'very strong constraints' exist on speech perception, even for early bilinguals, because L1 acquisition 'modifies the speech perception system' [Sebastián-Gallés and Soto-Faraco, 1999, p. 120]. If the findings of Flege et al. [1999a] generalize to the present study, then both groups of early bilinguals should identify English consonants as accurately as NE speakers. The findings of Sebastián-Gallés and Soto-Faraco [1999], on the other hand, would suggest that both groups of early Italian-English bilinguals would differ from the NE group. A third possibility, suggested by the foreign accent studies mentioned earlier, was that the early bilinguals who used Italian often, but not the early bilinguals who used Italian seldom, would differ from the NE subjects.

The third and final hypothesis tested here was that individual differences in PSTM would affect the native Italian subjects' identification of English consonants. There is often a great deal of intersubject variability in L2 speech research, especially among adult L2 learners [see e.g. Goto, 1971; Yamada et al., 1994]. For example, the native Japanese subjects examined by Bradlow et al. [1997] differed considerably in terms of how well they produced and perceived English /ɹ/ and /l/ before training, as well as how much they benefited from the training. Echoing the view of many previous researchers, Bradlow et al. [1997, p. 2306] noted that 'it is still unclear what specific factors determine individual performance'. Work by Service [1992] and Service and Kohonen [1995; see also Dufva and Voeten, 1999] suggested that variation in PSTM might influence success in learning an L2 in a classroom setting. As in previous studies, we assessed PSTM by having subjects repeat nonwords differing in number of syllables. If the findings of Service [1992] extend to naturalistic L2 learning, then PSTM might affect the native Italian subjects' ability to establish long-term memory representations for English consonants. If so, then the subjects who obtained high nonword repetition scores should identify English consonants more accurately than the subjects who obtained lower nonword repetition scores.

The Present Study

The stimuli for this study were natural tokens of 18 English consonants occurring in the initial and final position of nonwords. The stimuli were presented in four levels of masking noise in order to avoid ceiling effects. Five groups of subjects were tested. One consisted of NE subjects. Three consisted of native Italian subjects who differed according to AOA (designated 'early', 'mid', and 'late'). The fifth group consisted of native Italian subjects who had the same AOA as the subjects in the early group, but used Italian less. (This group was designated 'early-low'.)

We had two reasons to think that different results might be obtained for consonants in word-initial and word-final position. First, previous research has shown that nonnative speakers might not identify word-initial and word-final allophones of L2 consonants equally well. For example, Japanese lacks a liquid consonant that is similar to either English /ɹ/ or /l/. Japanese adults have been found to identify English liquids more accurately in word-final than word-initial position [e.g. Lively et al., 1993]. Moreover, different effects of training have been observed for liquids in word-initial and word-final position [Bradlow et al., 1997; see also Flege et al., 1996b]. Second, it was likely that the perceived relation between the word-initial and word-final English allophones examined here and the closest Italian consonant would differ. As is often the case in languages [Bell and Hooper, 1978], fewer consonants are permitted to occur in the final than in the initial position of Italian words. As summarized in table 1, six of the word-final English consonants examined here (/z θ v ʃ tʃ dʒ/), but only two word-initial English consonants (/z θ/) lack a phonetic counterpart in Italian [Agard and DiPietro, 1964]. Moreover, more English than Italian words end in a consonant [Carlson et al., 1985]. In fact, the Italian phonetic counterpart of seven of the word-final English consonants examined here (/p t k b d g f/) occurs at the end of few Italian words [Alinei, 1962].

Previous research suggested that the lexicophonetic differences just mentioned might result in interactions between word position and either AOA or L1 use. Costa et al. [1998, p. 1030] observed that listeners are sensitive to 'the repertoire of possibilities their language offers', including the overall distribution of phonetic elements. Flege and Wang [1990] compared two groups of Chinese subjects living in the United States. The subjects who spoke an L1 that permits word-final consonants (viz., Cantonese) identified the voicing feature in word-final English stops more accurately than did the speakers of an L1 that does not permit word-final obstruents of any kind (viz., Mandarin).[2] Another possibility was that the effect of PSTM, if one were observed, would be greater for the identification of word-final than word-initial English consonants, because a greater need would exist for the native Italian subjects to establish new long-term memory representations for stops in final than initial position.

[2] The distributional differences just mentioned might be extended to a subsegmental level as well. Gottfried and Beddor [1988] observed that native speakers of English made greater use of temporal cues than native speakers of French did when identifying the menbers of a French /o/-/ɔ/ continuum. This was attributed to a smaller effect of vowel duration on the identification of vowels by the native French subjects than by the NE subjects. According to the authors, this arose from a less extensive use of duration to distinguish vowels in French than English. A diminished (and, thus, more French-like) use of duration was observed for NE speakers of French, especially by individuals who were relatively proficient in French.

Table 1. English word-initial and word-final consonant allophones examined in an identification experiment, and the corresponding standard Italian allophone, if any, along with examples of lexical items containing the allophone (in parentheses)

Initial position				Final position			
English target		Italian counterpart		English target		Italian counterpart	
m	*(met)*	m	*(madre)*	m	*(dim)*	m	*(tram)*
n	*(net)*	n	*(nella)*	n	*(bin)*	n	*(con)*
s	*(set)*	s	*(soldi)*	s	*(bus)*	s	*(bis)*
ɹ	*(rat)*	r	*(radio)*	ɹ	*(bear)*	r	*(per)*
l	*(let)*	l	*(ladro)*	ɬ	*(bell)*	l	*(nel)*
pʰ	*(pit)*	p	*(padre)*	p	*(dip)*	p	*(stop)*[a]
tʰ	*(tot)*	t	*(tavolo)*	t	*(bit)*	t	*(est)*[a]
kʰ	*(cat)*	k	*(caldo)*	k	*(pick)*	k	*(cognac)*[a]
b	*(bet)*	b	*(bagno)*	b	*(sob)*	b	*(club)*[a]
d	*(debt)*	d	*(destra)*	d	*(sod)*	d	*(sud)*[a]
g	*(get)*	g	*(gomma)*	g	*(sag)*	g	*(zig-zag)*[a]
f	*(feet)*	f	*(figlio)*	f	*(laugh)*	f	*(golf)*[a]
v	*(vat)*	v	*(vita)*	v	*(dove)*		*
ʃ	*(shop)*	ʃ	*(sciare)*	ʃ	*(dish)*		*
tʃ	*(cheat)*	tʃ	*(cibo)*	tʃ	*(ditch)*		*
dʒ	*(jet)*	dʒ	*(giorno)*	dʒ	*(budge)*		*
θ	*(thought)*		*	θ	*(bath)*		*
z	*(zip)*		*	z	*(fizz)*		*

An asterisk indicates the absence of a word-initial or word-final allophone in Italian.

[a] Consonant allophones that occur in fewer than 20 Italian words, according to Alinei [1962].

In summary, the present study tested three hypotheses. The first was that the native Italian subjects' AOA would affect their identification of English consonants, with fewer errors being made by early than by late bilinguals. The second hypothesis was that L1 use would affect performance, with early bilinguals who seldom used Italian making fewer errors than early bilinguals who continued to use Italian relatively often. The third hypothesis tested here was that individual differences in PSTM would be related to the subjects' identification of English consonants, especially those found in word-final position.

General Method

Subjects

Given the aims of this study, it would have been ideal to recruit nine groups of subjects who differed orthogonally on the two primary variables of interest in this study, AOA and L1 use. However, this was not possible for practical reasons, so an 'L-shaped' research design was developed. It permitted us to compare three groups of native Italian subjects who differed primarily according to AOA and two groups of subjects (both consisting of early bilinguals) who differed primarily according to L1 use.

All 72 of the native Italian subjects (18 in each of four groups; see below) began to learn English when they emigrated from Italy to Canada. All but 2 native Italian subjects were from working-class

Table 2. Characteristics of the five groups of adult subjects who participated

	Gender	Age at time of testing	AOA in Canada	LOR in Canada	Percent use of Italian
Native English[a, b]	9 m, 9 f	48 (7)	–	–	–
Early-low[b]	9 m, 9 f	48 (5)	7 (3)	40 (5)	8 (6)
Early[a, b]	8 m, 10 f	47 (6)	7 (2)	40 (6)	32 (16)
Mid[a]	8 m, 10 f	48 (6)	14 (1)	34 (7)	20 (11)
Late[a]	8 m, 10 f	48 (6)	19 (1)	28 (5)	41 (23)
Mean	–	48 (6)	12 (6)	35 (7)	25 (19)

Age, AOA, and LOR are expressed in years. Standard deviations are in parentheses.
[a] Groups were compared to evaluate the effect of AOA.
[b] Groups were compared to evaluate the effect of L1 use (see text).

backgrounds, as indicated by parental occupation. All of the native Italian subjects were experienced in English, having lived in Canada for a minimum of 18 years (mean = 35). Most of them, as well as most of the 18 subjects in the monolingual NE control group, were recruited through a predominantly Italian Roman Catholic parish in Ottawa where testing was carried out. The mean age of the 90 subjects was 48 years (SD = 6). All 90 subjects passed a pure-tone hearing screening (defined using a 35-dB HL criterion at 500, 1,000, 2,000, and 4,000 Hz in the best ear) prior to participating, and no subject reported a history of auditory disorder.

As summarized in table 2, the subjects in three native Italian groups were selected on the basis of AOA (early: 7, mid: 14, late: 19 years). The early-low group was then formed by recruiting subjects having the same average AOA as the subjects in the early group but who used Italian less (early-low: 8%, early: 32%). As in previous research [e.g. Flege et al., 1995b; Yamada, 1995], AOA was inversely correlated with the native Italian subjects' LOR in Canada [$r(70) = –0.62$, $p < 0.01$]. This led to a significant effect of Group on LOR [$F(3, 68) = 16.1$, $p < 0.01$]. Also, the earlier the native Italian subjects arrived in Canada, the less schooling they had received in Italy. The difference between groups in years of schooling in Italy (early-low: 1.8 years, early: 1.9 years, mid: 6.6 years, late: 8.5 years) was significant [$F(3, 68) = 46.3$, $p < 0.01$].

The native Italian subjects were asked a number of questions pertaining to where and with whom they used Italian. The responses to these questions suggested that the subjects in the early-low group tended to use Italian mostly when visiting relatives. They reported being less likely than the subjects in the early group to use Italian at home, at work, on the telephone, or at social gatherings. We had reason to think that the subjects' self-reports concerning the amount of L1 use were reliable and valid. A strong correlation existed between the estimates of percentage Italian use given by 62 subjects in the present study and the estimates given by the same subjects in a study 3 years earlier [Flege et al., 1995b, $r(60) = 0.84$, $p < 0.01$]. This suggested that the subjects' language use patterns were fairly stable. Finally, there was a strong inverse correlation between the subjects' estimates of English and Italian use, which occurred on separate portions of the language background questionnaire [$r = –0.96$, d.f. = 70, $p < 0.01$].

The following test was carried out to evaluate the validity of the native Italian subjects' estimates of L1 use. If subjects in the early-low group really did use Italian less than those in the early group, they might be less competent in Italian than subjects in the early group. Competence in Italian was evaluated by examining the frequency of errors the native Italian subjects made in the extremporaneous production of Italian. A native Italian speech-language pathologist, who was blind as to the group membership of the subjects, orthographically transcribed recorded speech samples. She noted all grammatical errors involving noun-phrase agreement, subject-verb agreement, prepositions, verb tense, auxiliary verbs, and pronouns. Lexical errors were also noted. (Divergences from standard Italian that could be attributed to dialect influences were not counted as errors.)

The percentage of errors made by each subject was calculated by dividing the number of errors observed for each subject by the number of content words they had produced.[3] The difference in the mean percentage of errors observed for the four native Italian groups (early-low: 14%, early: 11%, mid: 9%, late: 7%) was significant [$F(3, 68) = 8.21$, $p < 0.01$]. A Tukey's test revealed that subjects in the early group made more errors than did subjects in the late group, whereas the subjects in the early-low group made errors than did subjects in both the mid and late groups ($p < 0.05$). This is consistent with the view that the subjects in the early-low group were less competent in Italian than were those in the early group.

Procedure

The subjects participated in several experiments during two 1-hour sessions. An experiment examining the subjects' identification of English consonants in noise will be presented below. Also presented below is a nonword repetition test that was carried out to assess PSTM. The subjects repeated semantically unpredictable English sentences that were presented in noise to provide an assessment of their ability to recognize English words [Meador et al., 2000]; their production and perception of English vowels was assessed in two other experiments [Flege et al., 1999a]. Finally, the subjects repeated English sentences, which were later evaluated for degree of foreign accent [Piske et al., under review], and responded extemporaneously to questions posed in English and Italian (see above).

Consonant Identification

The purpose of this experiment was to evaluate the effect of AOA and L1 use, if any, on the native Italian subjects' identification of English consonants. Most previous L2 research has focused in detail on just a few L2 consonants [e.g. Lively et al., 1993; Flege et al., 1996a], but we chose to examine 18 consonants of English.[4] This approach prevented us from obtaining a large number of judgments of each consonant and, thus, limited our ability to draw inferences concerning the use of specific features, or the effect of variation in cross-language phonetic distance, on the identification of various consonants. However, given that relatively few L2 consonants are likely to be misidentified frequently [Nabèleck and Donahue, 1984; Sekiyama and Tohkura, 1993], the approach adopted here was likely to increase the possibility of finding significant between-group differences.

Another approach used here to increase the chance of finding between-group differences was to embed the English consonants in noise. We are not aware of a previous study that has focused on the identification of L2 consonants in noise. However, Mayo et al. [1997] examined the recognition of sentence-final words that were either predictable from the preceding context or unpredictable. Subjects who began learning English as an L2 by the age of 6 years needed significantly higher signal-to-noise (S/N) levels than NE subjects did in order to identify 50% of both the predictable and unpredictable words. The early bilinguals were more tolerant of noise for predictable words (but not for unpredictable words) than were bilinguals who began learning English

[3] The average number of content words produced by subjects in the four native Italian groups (early-low 156, early 162, mid 206, late 162) did not differ significantly [$F(3, 68) = 1.72$, $p > 0.10$].

[4] We chose not to examine glides or the sounds /ŋ/ or /ʒ/ because they do not occur in both word-initial and word-final position. We excluded /ð/ because of difficulty in finding an unambiguous orthographic representation for it.

somewhat later in life. McAllister [1990] found that nonnative speakers needed S/N levels that were 4–6 dB greater than native speakers did in order to identify 50% of the test materials.

Method

Stimuli

An adult male native speaker of American English produced the 18 consonants listed in table 1 in the context of /_ɑdo/ and /hodɑ_/, yielding 36 nonwords. Nonwords[5] were examined to minimize lexical bias effects [Flege et al., 1996b] and possible AOA-related differences in the use of contextual information [Mayo et al., 1997]. Some of the English consonants that might be said to have an Italian counterpart (table 1) differed phonetically from their Italian counterpart. English /ɹ/ differs from its Italian counterpart in both word positions, whereas English /l/ differs from Italian /l/ only in final position, where it is velarized. The English /p t k/ tokens used here were produced with more aspiration in initial position than is typical for Italian /p t k/; those in final position were released, as is typical for word-final stops in Italian. The initial /b d g/ tokens used here resembled the corresponding Italian stops in that they were prevoiced; the final-position /b d g/ tokens were partially devoiced and released.

The /Cɑdo/ and /hodɑC/ stimuli averaged 604 and 648 ms in duration, respectively. The 36 stimuli were normalized for peak intensity (50% of the full scale), then embedded in the center of four 1,000-ms pink noise segments that were ramped on over the first 30 ms and ramped off over the final 20 ms. This yielded stimuli having S/N ratios of 12, 6, 0, and –6 dB.[6]

Procedure

The subjects were tested individually in a quiet room. The stimuli were presented using a notebook computer (Texas Instruments Model 570CDT) via headphones (Sennheiser Model HD535). Before the experiment began, the subjects adjusted the volume to a comfortable level. Disyllables resembling the test stimuli were played out until the subjects confirmed hearing the stimuli 'clearly'. The initial and final stimuli were presented in separate counterbalanced blocks. In each, the S/N level decreased in the same fixed order: 12, 6, 0, and finally –6 dB. This approach was adopted to help ensure that no group, including the NE group, performed at ceiling. We reasoned that making the stimuli progressively more noisy would work against the tendency for errors to decrease in frequency as the subjects gained familiarity with the stimuli.

The subjects were told to identify the initial or final consonant by selecting one of five written response alternatives, of which one was the correct response and four were foils. For example, the orthographic response alternatives that were offered for the /s/ in /sɑdo/ were S- (the correct response), TH-, SH-, F-, and T- (foils); the response alternatives offered for the /v/ in /vɑdo/ were V- (the correct response), TH-, B-, Z-, and F- (foils). English spelling conventions were used for both the target consonants and foils. The correct response occurred with equal frequency in all five possible positions. The four foils identified for each target consonant were the consonants that, in previous research [Bell et al., 1989; Miller and Nicely, 1955; Wang and Bilger, 1973; Wang et al., 1978], were most likely to be confused with the target consonant. The majority of foils differed from the target according to place and/or manner of articulation.

The subjects were not trained on the identification task, but they were given practice before each block with nontest stimuli presented at an S/N level of 12 dB. The interval between each response and

[5] The fact that a few of the stimuli (e.g. 'cado', 'bado', 'dado') formed words in Italian might have provided an advantage to certain native Italian subjects, thereby reducing the size of the native versus nonnative differences observed here.

[6] The final consonant stimuli actually had S/N ratios of 11, 5, –1, and –7 dB, due to acoustic differences in the initial and final consonant allophones and the presence of an /h/ at the beginning of the final-consonant stimuli. For the sake of simplicity, these small S/N differences between the initial and final stimuli will not be referred to in the text.

the next trial fixed at 1.0 s. The subjects were told to guess if uncertain. The percentage of errors each subject made identifying word-initial and word-final consonants at the four S/N levels was calculated. Each of the 8 error scores was based on a maximum of 18 possible errors.

Results

As the stimuli became increasingly noisy, the subjects made increasingly more errors identifying consonants in both word-initial position (12 dB: 17%, 6 dB: 24%, 0 dB: 38%, –6 dB: 61%) and word-final position (12 dB: 14%, 6 dB: 22%, 0 dB: 40%, –6 dB: 55%). There were more consonant identification errors, on the average, for consonants in initial position (mean = 35%) than in final position (mean = 33%). A preliminary 5 (Group) X 2 (Consonant Position) X 4 (S/N Level) ANOVA was undertaken to determine if the effect of S/N Level was comparable for the five groups of subjects. It yielded a significant main effect of S/N Level [$F(3, 255) = 1{,}085$, $p < 0.01$]. S/N Level did not interact significantly with Group [$F(12, 255) = 1.13$, $p > 0.10$] or enter into a significant three-way interaction [$F(12, 255) = 0.79$, $p > 0.10$].

The lack of a Group X S/N Level interaction diverges from the results of previous studies [McAllister, 1990; Mayo et al., 1997], perhaps because this study focused on the identification of consonants in isolated nonwords, rather than the recognition of words in longer stretches of speech. Another possible basis for the apparent difference between this study and the others is that the subjects examined here were more experienced in their L2 than were the subjects examined in previous studies. Examining the effect of noise on nonnative subjects' perception was not a focus of the present study. Therefore, the finding just presented will not be discussed further, and all subsequent analyses will focus on percent error scores that were averaged over the four S/N levels. Each of these scores was based on 72 forced-choice judgments (18 consonants X 4 S/N levels).

The purpose of the first analysis was to examine the effect of AOA. The scores obtained for the NE subjects were compared to the scores obtained for three groups of native Italian subjects who differed primarily according to AOA (early, mid, late). For the purpose of this analysis, the NE subjects' AOA might be regarded as 0, for they were born in an English-speaking community in Canada. As shown in figure 1a, the NE subjects made fewer errors on the average (mean = 27%) than did the subjects in the three native Italian groups (early: 36%, mid: 35%, late: 39%). The NE subjects made somewhat more errors for initial than final consonants (means = 30 vs. 24%), as did the subjects in the mid group (36 vs. 34%) and late group (40 vs. 39%). However, the subjects in the early group made somewhat fewer errors for initial than final consonants (35 vs. 37%).

The percent error scores were submitted to a 4 (Group) X 2 (Consonant Position) ANOVA. It yielded a significant main effect of Group [$F(3, 68) = 11.9$, $p < 0.01$], a marginally significant effect of Position [$F(1, 68) = 3.8$, $p = 0.056$], and a significant two-way interaction [$F(3, 68) = 3.4$, $p < 0.05$]. Simple effects tests revealed that the two-way interaction arose because the effect of Position was significant for the NE subjects [$F(1, 17) = 27.3$, $p < 0.01$] but was nonsignificant for all three native Italian groups [early: $F(1, 17) = 0.6$, mid: $F(1, 17) = 1.1$, late: $F(1, 17) = 0.3$, all p values > 0.10]. That is, the NE subjects made more errors identifying initial than final consonants, whereas the effect of position was nonsignificant for the native Italian subjects.

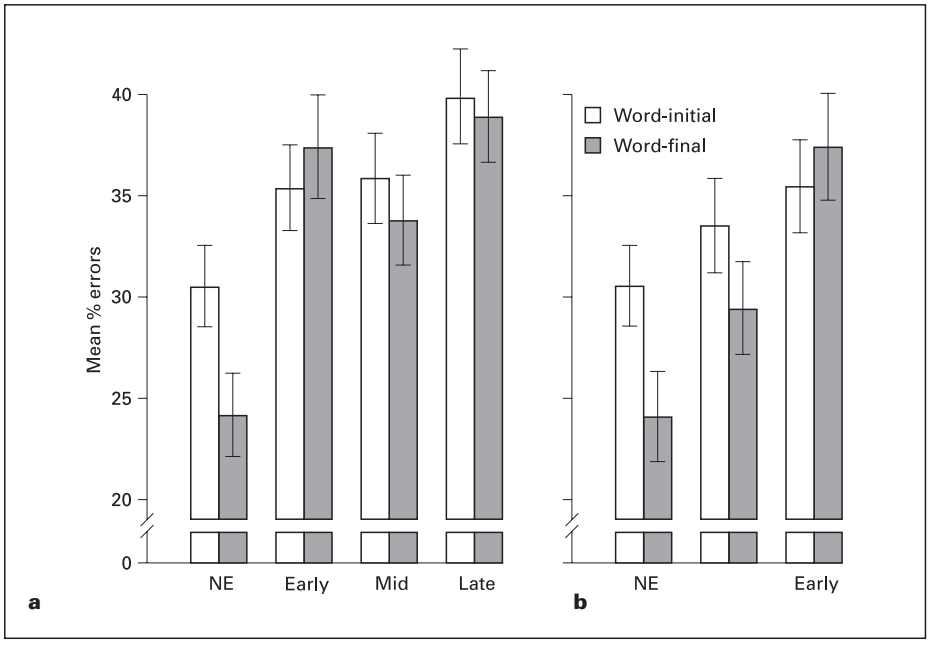

Fig. 1. The mean percentage of errors made in the identification of word-initial and word-final English consonants by three groups of native Italian subjects who differed according to AOA in Canada (**a**) and two groups of early bilinguals who differed according to self-reported use (see text, **b**). The data for the NE and the Early groups are shown in both panels. The brackets enclose ± 1 standard error.

All three groups of native Italian subjects identified the English consonants less accurately than the NE subjects did. The simple effect of Group was significant for consonants in both word positions [initial: $F(3, 68) = 10.4$; final: $F(3, 68) = 9.2$, $p < 0.01$]. Tukey's tests revealed that, for both initial and final consonants, all three native Italian groups made significantly more errors than the NE subjects did ($p < 0.05$). The Tukey's tests failed to reveal any significant differences between the three native Italian groups, either for initial or final consonants ($p > 0.10$). This finding suggested that AOA did not affect the native Italian subjects' accuracy in identifying English consonants in noise.

The purpose of the next analysis was to examine the effect of L1 use by comparing the scores obtained for the two groups of early bilinguals who differed according to L1 use (early-low, early) to those obtained for the NE subjects. The scores obtained for the subjects in the early-low group, who used Italian seldom, have been juxtaposed in figure 1b to the scores obtained for the NE and early groups (previously shown in fig. 1a). The average percentage of errors made by the subjects in the early-low group was intermediate (mean = 31%) to the percentages of errors observed for the NE and early groups (means = 27 and 36%). Like the NE subjects, the subjects in the early-low group made more errors identifying consonants in initial than final position (means = 33 vs. 29%). The subjects in the early-low group, therefore, differed from the subjects in the early group, who made somewhat fewer errors for initial than final consonants.

A 3 (Group) X 2 (Consonant Position) ANOVA yielded significant main effects of Group [$F(2, 51) = 11.3$, $p < 0.01$] and Consonant Position [$F(1, 51) = 6.9$, $p < 0.05$]. The significant two-way interaction [$F(2, 51) = 5.3$, $p < 0.01$] yielded by the ANOVA had two sources. One was a differing effect of word position for the two groups of early bilinguals. The Position factor was significant for the NE group [$F(1, 17) = 27.3$, $p < 0.01$] and the early-low group [$F(1, 17) = 6.3$, $p < 0.05$] but not the early group [$F(1, 17) = 0.6$, $p > 0.10$]. The other source of the interaction was a differing pattern of between-group differences for initial and final consonants. The simple effect of Group was significant in both word positions [initial: $F(2, 51) = 4.9$; final: $F(2, 51) = 10.7$, $p < 0.05$]. Tukey's tests revealed that the subjects in the early group made more errors for both initial and final consonants than the NE subjects did, whereas the subjects in the early-low group did not differ significantly from the NE subjects for consonants in either position ($p > 0.10$). The subjects in the two early bilingual groups did not differ significantly for initial consonants; however, the early group made more errors identifying final consonants than the subjects in the early-low group did ($p < 0.05$).

Discussion

The results obtained here indicated that native speakers of Italian who continued to use their L1 fairly often (i.e. subjects in the early, mid, and late groups) identified English consonants less accurately than NE subjects did. The consonant identification errors observed here probably cannot be attributed to a lack of experience with the English sound system, for the native Italian subjects had lived in Canada for an average of 35 years. It seems reasonable to conclude that cross-language phonetic differences resulted in persistent native versus nonnative differences in the native Italian subjects' identification of at least some English consonants. This conclusion agrees with the results of previous studies that have examined specific L2 consonants [e.g. Lively et al., 1993; Flege et al., 1996a, b; Bradlow et al., 1997]. The difference between the NE group and the early group is notable in that the subjects in the early group arrived in Canada at an average age of 7 years. It is, therefore, unlikely that they differed from the NE subjects as the result of having passed a critical period for L2 speech learning [e.g. Scovel, 1988].

We did not observe a significant difference between three groups of native Italian subjects who differed primarily according to AOA (viz., early, mid, late). The lack of an effect of AOA for consonant identification diverged from the observation of an AOA effect for categorial discrimination of English vowels [Flege et al., 1999a]. We, therefore, explored the possibility that the null effect of AOA in the present study was due to sampling error. As will be discussed in the next section, individual differences existed in the native Italian subjects' ability to repeat nonwords. This suggested differences in PSTM, which has been linked to aspects of both L1 learning [Gathercole and Baddeley, 1993] and L2 learning [Service, 1992; Service and Kohonen, 1995; Dufva and Voeten, 1999].

The consonant identification scores obtained for the subjects in the NE, early, mid, and late groups were reanalyzed using the nonword repetition scores as a covariate. The ANCOVA yielded a significant main effect of Group [$F(3, 67) = 14.7$, $p < 0.01$], a marginally significant main effect of Consonant Position [$F(1, 68) = 3.8$, $p = 0.056$], and a significant two-way interaction [$F(3, 68) = 3.4$, $p < 0.05$]. As in the ANOVA pre-

sented earlier, the simple effect of Group was significant for the consonants in both word positions [initial: $F(3, 67) = 12.8$; final: $F(3, 67) = 10.9$, $p < 0.01$]. And, as in the analysis presented earlier, a Tukey's test revealed no significant differences between the three native Italian groups for word-final consonants. However, the subjects in the late group made significantly more errors for word-initial consonants than the subjects in the early group did ($p < 0.01$). That is, when the nonword repetition scores were used as a covariate, an AOA effect was observed for word-initial consonants.

It is uncertain why an AOA effect was observed in the ANCOVA for consonants in initial but not final position. Phonetic inventory differences between English and Italian (table 1) and a difference in the relative frequency of occurrence of final consonants [Carlson et al., 1985] might have contributed to this finding. We speculate that the native Italian subjects' learning of word-final English consonants was impeded to a smaller extent by cross-language interference than their learning of word-initial consonants was [see e.g. Flege, 1995]. Unfortunately, the data now in hand do not permit a firm conclusion to be reached. As mentioned earlier, just a single token of each consonant was presented at each S/N level. This precluded reaching a general conclusion about the identification of any particular consonant or subset of consonants. Additional work is clearly needed.

A second important finding obtained here was the observation of an effect of L1 use on L2 consonant identification. The early bilinguals who continued to use Italian often (early), but not the early bilinguals who seldom used Italian (early-low), made more consonant identification errors than the NE subjects did. And the subjects in the early group made significantly more errors identifying word-final consonants than the subjects in early-low group did. These findings suggest that if a bilingual's L1 remains strong and active, it will influence the identification of at least some phonetic segments in an L2, even if the L2 is learned in childhood [see also Sebastián-Gallés and Soto-Faraco, 1999]. The early bilinguals who differed according to L1 use also showed different effects of word position. The subjects in the NE and early-low groups made significantly more errors for consonants in initial than final position, whereas the subjects in the early group showed a nonsignificant trend in the opposite direction.

The position effect observed here for the NE and early-low groups might seem counterintuitive for three reasons. First, word recognition models attribute a special prominence to the beginning of words [e.g. Marslen-Wilson and Welsh, 1978]. However, the studies reviewed by Protopapas [1996] suggested that acoustic information at the end of words might be just as important for word recognition as the information found at the beginning of words. Second, Redford and Diehl [1999] provided evidence that certain word-initial English consonants are more distinct acoustically than their word-final allophones are. However, L2 learners may be better able to identify certain word-final than word-initial English consonant allophones for acoustic reasons. For example, Lively et al. [1993] suggested that Japanese adults identify English liquids (/ɹ/, /l/) at higher rates in word-final than word-initial position, because English liquids have longer transitions in final than initial position and because information relevant to the identity of final liquids resides in the preceding vowel due to coarticulation. A third reason why the NE subjects' final-position advantage might seem counterintuitive is that several studies have reported an initial-position advantage for NE-speaking listeners [e.g. Dubno and Levitt, 1981; Gelfand et al., 1985; Redford and Diehl, 1999]. However, the final-position advantage reported here for NE subjects (and also for early

bilinguals who seldom used their L1) agrees with the results of other studies [Wang and Bilger, 1973; Bilger and Wang, 1976; Helfer, 1994].

The results in hand do not provide a ready explanation for the apparent divergences across studies regarding the effect of word position on consonant identifiability. One possibility that should be examined in future research is that a final-position advantage may be obtained when, as in the present study, a wide range of consonants are examined in a single set, thus creating a wide range of possible perceptual confusions.

Nonword Repetition Test

As mentioned in the last section, we obtained a modest effect of AOA for initial consonants when the scores obtained on a nonword repetition test were used as a covariate in an ANCOVA. An AOA effect was not obtained in an ANOVA, however. This suggested that individual differences might have obscured the observation of an AOA effect.

Individual differences in L2 speech learning have been attributed in the literature to a wide range of factors, including degree of motivation [e.g. Gardner, 1985], attitude [e.g. Schumann, 1986], and aptitude. L2 learning aptitude research, in turn, has pointed to at least three distinct components: phonemic coding ability, language analytic ability, and working memory [see Skehan, 1989, for review]. Phonemic coding ability might be described as the capacity to discriminate and code foreign language sounds in a way that permits their later recall [Carroll, 1981]. Limitations on the size of working memory might reduce the likelihood that input will be encoded effectively and stored successfully in long-term memory.

The primary aim of this experiment was to determine if variation in working memory might have influenced the native Italian subjects' identification of English consonants. A number of studies have suggested that limitations of a specific kind of working memory, PSTM, may slow vocabulary development during native language acquisition and be associated with difficulty in learning to read [Gathercole and Baddeley, 1993]. There is also some evidence that variation in PSTM might influence the degree of success in learning an L2 in a classroom setting [Service, 1992; Service and Kohonen, 1995]. As far as we know, variation in PSTM has not previously been linked to the production or the perception of L2 speech sounds.

The 90 subjects described earlier were asked to repeat Italian nonwords varying in number of syllables. PSTM was estimated by determining the percentage of nonwords each subject repeated correctly. It seemed possible that the NE subjects would obtain somewhat lower nonword repetition scores than the native Italian subjects did. If so, this would probably not indicate a difference in PSTM because the nonwords were created from Italian CV syllables and were, therefore, likely to be less wordlike for the native English subjects than for the native Italian subjects [see van Bon and van der Pijl, 1997]. Our working assumption was that PSTM is normally distributed. We, therefore, did not expect to find significant differences between the four native Italian groups. Our primary aim was to learn if intersubject differences in PSTM among the native Italian subjects would influence the long-term representations they established for English consonants, resulting in a measurable variation in the consonant identification scores reported in the previous section.

Table 3. Stimuli used in the nonword repetition task

Number of syllables			
2	3	4	5
/vako/	/finoko/	/vesobeko/	/vasomuniko/
/nuto/	/meloto/	/bulovato/	/lofidanuto/
/bulo/	/danilo/	/benofilo/	/nomusubemo/
/tʃemo/	/buvomo/	/sodavemo/	/tʃesubefimo/
/mudo/	/limedo/	/nivobudo/	/benitʃemudo/
/soko/	/nosuko/	/lofitʃemo/	/kavebuliko/
/vato/	/nitʃeto/	/muliveto/	/bumekasuto/
/dalo/	/tʃenulo/	/tʃemusulo/	/vonulidalo/

All of the items were formed by splicing together Italian CV syllables, and all had stress on the penultimate syllable.

Method

Stimuli

Repeating a nonword subsumes at least three distinct psycholinguistic processes. The vowels and consonants (or syllables) making up the nonword must first be identified. The coded units must be held in memory while subsequent sounds (or syllables) are processed. Finally, motoric codes for each sound (or syllable) must be formulated and the nonword produced. Our primary interest was in the second step. We anticipated that the native Italian subjects would have less difficulty identifying Italian than English CV syllables. We, therefore, decided to examine nonwords made from Italian rather than English CVs.

As shown in table 3, the stimuli for this experiment were eight nonwords each having 2, 3, 4, and 5 syllables. The nonword stimuli were created by concatenating CV syllables. This novel technique was adopted to minimize the reduction in spectral quality or duration in phonetic segments that arises when the number of syllables in a word increases. The CV syllables used to form the nonwords were edited out of either the first (/vo/, /so/, /va/, /fi/, /ve/, /su/, /ni/, /me/, /nu/, /mu/, /no/, /da/, /be/, /tʃe/, /bu/, /ka/, /li/, /lo/) or the second syllable (/do/, /ko/, /to/, /lo/, /mo/) of real Italian CVCV words that were produced by an adult female native speaker of Italian. The final-position CVs were always placed in the final syllable of the nonwords, and the nonfinal position CVs were always placed in a nonfinal syllable of the nonwords. The impression of uniform stress on the penultimate syllable of the nonwords was achieved by lengthening that syllable by 60–100 ms (by repeating 8–12 nonadjacent glottal pulses) and increasing its intensity by 3–5 dB.

Procedure

The nonwords were presented in the quiet via loudspeakers. The subjects were told to repeat as much of each 'foreign word' as possible. They were given practice with four nontest items (/medo/, /subemo/, /suvokado/, /fivonumedo/) before the repetition task began. The practice items were presented in order of increasing length, twice in a row. During the repetition task itself, the nonword stimuli were presented one time each in separate blocks in increasing order of length (first the 2-syllable nonwords, then the 3-syllable nonwords, and so on). The subjects' responses were recorded using a head-mounted microphone (Shure Model SM10A) and a portable DAT tape recorder.

The recordings were later digitized, then transcribed by a NE-speaking phonetician. Each syllable was classified as having been repeated correctly if both its vowel and consonant were repeated correctly. A liberal standard for 'correctness' was adopted to ensure that productions that might be attributed to differences between Italian and English or between Italian dialects (or varieties) were not

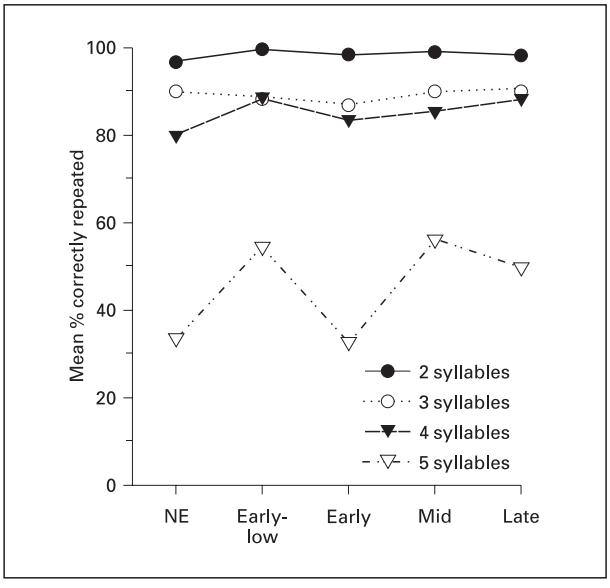

Fig. 2. The mean percentage of nonwords made up of 2–5 syllables that were repeated correctly by the subjects in five groups.

counted as errors.[7] Each nonword was classified as having been repeated correctly, in tum, if all of its constituent syllables were repeated correctly. Finally, the percentage of the 2-, 3-, 4-, and 5-syllable nonwords (maximum = 8 each) repeated correctly was calculated for each subject.

Results

Nonword Repetition Scores

The mean percentages of nonwords that subjects in the five groups repeated correctly are shown in figure 2. The nonword repetition scores decreased as the number of syllables increased (2-syllable nonwords: 98%, 3-syllable: 88%, 4-syllable: 84%, 5-syllable: 45%). The scores obtained for the five groups differed little overall (NE: 75%, early-low: 82%, early: 75%, mid: 82%, late: 81%). However, somewhat larger between-group differences were evident in the 5-syllable nonwords than for the nonwords containing fewer syllables.

The nonword repetition scores were examined in a 5 (Group) $\times$ 4 (Syllable Length) ANOVA. This analysis yielded a significant main effect of Group [$F(4, 85) = 2.5$, $p < 0.05$], a significant main effect of Length [$F(3, 255) = 244.1$, $p < 0.01$], and a significant two-way interaction [$F(12, 255) = 2.6$, $p < 0.01$]. The interaction arose because a difference between groups existed only for the longest nonwords. The simple effect of Group was nonsignificant for the nonwords containing 2–4 syllables [2-sylla-

[7] For example, changes in vowel height and frontness/backness (e.g. a rendition of /e/ as [ɪ]) were counted as an error but not changes in tensity or degree of formant movement in vowels (e.g. the rendition of /e/ as [eɪ] or as [ɛ]). Place of articulation changes in consonants (e.g. /k/ for /t/) and other manner changes (e.g. /b/ for /v/) were counted as errors but not voicing changes (e.g. a rendition of /z/ as [s]).

Table 4. Simple correlations observed for 72 native speakers of Italian

		2	3	4	5	6	7	8
1	Chronological age	0.12	0.68***	0.04	0.12	0.02	0.24*	0.01
2	AOA in Canada		0.62***	0.39***	–0.49***	0.12	0.43***	0.30*
3	LOR in Canada			–0.26*	0.44***	–0.10	–0.10	–0.21
4	Self-reported use of Italian, %				–0.30**	–0.02	0.22	0.22
5	Errors in extemporaneous Italian, %					–0.31**	0.02	0.14
6	Nonword repetition scores						–0.29*	–0.42***
7	Errors, initial consonants, %							–0.53***
8	Errors, final consonants, %							

*p < 0.05; **p < 0.01; ***p < 0.001.

ble: F(4, 85) = 0.7; 3-syllable: F(4, 85) = 0.2; 4-syllable: F(4, 85) = 0.7, p > 0.10], but it was significant for the 5-syllable nonwords [F(4, 85) = 4.0, p < 0.01]. A Tukey's test revealed that the subjects in the early group correctly repeated fewer nonwords containing five syllables than did the subjects in the mid group (p < 0.05). No other between-group differences reached significance.

Regression Analyses

Our next aim was to determine if the nonword repetition scores just presented could account for a significant amount of variance in the consonant identification scores presented in the last section. Before carrying out multiple regression analyses, we examined the simple correlations between the variables involved. Table 4 summarizes the simple correlations that were obtained for the 72 native Italian subjects. Correlations were calculated for chronological age, AOA, LOR in Canada, self-reported percentage use of Italian (table 2), the percentage of errors the native Italian subjects made when speaking Italian extemporaneously (see the 'General Method' section), the nonword repetition scores just presented, and the word-initial and word-final consonant identification error scores presented in the last section. Significant negative correlations were found to exist between the nonword repetition scores and the percentage of errors the native Italian subjects made identifying both word-initial and word-final English consonants. That is, the more Italian nonwords the subjects were able to repeat, the fewer errors they tended to make identifying English consonants presented in noise. This might be taken as support for the hypothesis that a link exists between PSTM and nonnative subjects' ability to identify L2 consonants. This conclusion receives additional support from the observation that although AOA was correlated with the consonant error scores, the conrelation between AOA and the nonword repetition scores was nonsignificant.

Two hierarchical regression analyses were carried out. One examined the percentage of errors made in the identification of word-initial consonants; the other examined errors for word-final consonants. The predictor variables were age, AOA, LOR, L1 use, the percentage of errors in extemporaneous Italian (i.e. the 'L1 error' scores), and

Table 5. Results of hierarchical regression analyses examining the percentage of errors made by the native Italian subjects in the identification of word-initial and word-final English consonants

Dependent variable	Independent variables	Beta	R^2	R^2 change	F
Percentage of word-initial consonant errors	AOA	–0.561	0.181	0.181	18.3*
	% errors in Italian nonword repetition	–0.204	0.250	0.070	7.0*
		0.293	0.328	0.078	7.8*
		$F(3, 68) = 11.1, p < 0.0001$			
Percentage of word-final consonant errors	AOA	–0.498	0.087	0.087	8.9*
	% errors in Italian nonword repetition	–0.232	0.190	0.102	10.9*
		0.405	0.338	0.148	15.1*
		$F(3, 68) = 11.6, p < 0.0001$			

An asterisk indicates significance at the 0.01 level.

the nonword repetition scores. In both analyses, the first four predictor variables (age, AOA, LOR, L1 use) were entered at step 1, the L1 error scores were entered at step 2, and the nonword repetition scores were entered at step 3. Thus, if the nonword repetition scores accounted for a significant amount of variance in the word-initial or word-final error scores, it would indicate that it did so independently of the other predictor variables.

As summarized in table 5, a significant 33% of the variance in word-initial consonant error scores was accounted for, and a significant 34% of variance in the word-final error scores was accounted for ($p < 0.01$). The L1 error scores accounted for roughly the same amount of variance in the word-initial and word-final consonant error scores (7 vs. 10%). This suggested that the stronger was the L1 system of the native Italian subjects, the less accurately they tended to identify English consonants. AOA accounted for more variance in the word-initial than word-final consonant error scores (18 vs. 9%). Most importantly, the nonword repetition scores accounted for a significant amount of variance in both analyses. These scores accounted for somewhat more variance in the subjects' identification of English consonants in word-final than in word-initial position (15 vs. 8%).

General Discussion

One question addressed by this study was whether the native Italian subjects' age of first extensive exposure to English, which occurred when they immigrated to Canada from Italy, would affect their identification of English consonants presented in noise. To this end, we compared the performance of three groups of subjects who continued to speak Italian fairly often but differed according to the age at which they arrived in Canada (early: 7, mid: 14, late: 19 years). All three native Italian groups made more identification errors than the native English group did. The difference between the NE subjects and these 54 native Italian subjects (3 groups × 18) was clearly not due to a lack of experience in English. The native Italian subjects in the

early, mid, and late groups had lived in Canada for at least 18 years (mean = 35) and reported using English 69% of the time, on the average (range: 10–95%). Only 7 (13%) of them reported using Italian more than English, and 73% of them indicated that they would choose English if they could retain only one of their two languages.

The results obtained here for the early group agree in part with the results obtained for early Spanish-Catalan bilinguals by Sebastián-Gallés and Soto-Faraco [1999]. The early bilinguals in that study needed to hear longer portions of intervocalic /ʃ/ and /ʒ/ tokens to identify these fricatives correctly than did native speakers of Catalan. However, the early bilinguals did not differ from the native speakers for /s/-/z/, perhaps because /s/ exists in Spanish. Our finding for the early group in this study also supports a conclusion drawn by Calderón and Best [1996]. These authors examined the discrimination of stop consonants in an unknown foreign language (Xhosa) by English monolinguals and native speakers of Spanish who had learned English as young children. The discrimination errors made by the English monolinguals and the early Spanish-English bilinguals varied considerably, suggesting that the impact of early phonetic learning in the L1 may persist into adulthood [see also Pallier et al., 1997; Sebastián-Gallés and Soto-Faraco, 1999].

A recent study that examined the native Italian subjects' categorial discrimination of vowels revealed an effect of AOA. The subjects in the late group made more errors discriminating English vowels than the subjects in the early group did [Flege et al., 1999a]. Based on this finding, we expected to observe an effect of AOA on consonant identification in the present study. When an AOA effect was not observed, we reexamined the consonant identification scores in an ANCOVA using the scores obtained on a nonword repetition task as a covariate. In the reanalysis, the subjects in the late group were found to have made significantly more errors identifying word-initial consonants than the subjects in the early group did. However, the effect of AOA on the identification of word-final consonants remained nonsignificant.

Additional research will be needed to clarify the basis for AOA effects in L2 speech research. We can probably reject the view that the subjects in the early group misidentified English consonants more frequently than the NE subjects because they had passed a neurologically based critical period [e.g. Scovel, 1988]. This is because subjects in the early group began attending English-speaking schools soon after arriving in Canada at an average age of 7 years. Several different explanations might be offered for why the late bilingual differed from the NE subjects. Late bilinguals might learn to perceive L2 consonants less accurately than early bilinguals because of lost neural plasticity [Scovel, 1988]. AOA effects might arise from social variables that are typically confounded with AOA, such as amount of education in L2-speaking schools or how much the L2 is used [e.g. Flege, 1998; Flege et al., 1999b]. Still another possibility is that AOA-effects are due to a confounded phonetic factor. As the phonetic category representations for L1 sounds develop over childhood and into adolescence, they might be more likely to perceptually assimilate L2 sounds and, thus, block the formation of new phonetic categories for L2 sounds [Flege, 1995].[8] This last explanation

[8] Although neurological development and L1 speech development may covary in children and adolescents, the two hypotheses just mentioned are distinct. The maturational hypothesis predicts that the L1 will influence the L2, but not the reverse. The Speech Learning Model [Flege, 1995], on the other hand, predicts mutual effects of phonic units of the L1 and L2 on one another. The nature and magnitude of such effects will depend, in part, on the nature of the long-term memory representations for L1 phonetic categories when L2 learning commences.

rests on the assumption that the phonic elements of a bilingual's L1 and L2 exist in a 'common phonological space', and, thus, may mutually influence (or 'interfere with') one another to some extent.

The last explanation just mentioned focuses on the nature of long-term memory representations ('phonetic categories') that are developed for speech sounds in the L1 and L2 and how (or if) these representations interact in bilinguals [see Flege, 1995]. Differences in long-term memory representations between native and nonnative speakers are known to slow early stages of phonetic processing [e.g. Costa et al., 1998], as well as to impair nonnatives' perception of synthetic speech [Greene et al., 1985] and distorted natural speech [Nabèleck and Donahue, 1984]. If one considers just the consonants that occur in a wide range of Italian words, only five of the 18 word-final English consonants that were examined in this study might be said to have an Italian phonetic counterpart, as compared to 16 of the 18 word-initial consonants (table 1). By hypothesis [Flege, 1995], L2 learners of all ages remain able to establish long-term memory representations for L2 sounds that are (or come to be) perceived as phonetically distinct from the closest L1 sound. However, the likelihood of category formation is hypothesized to decrease with age for sounds of a particular degree of perceived cross-language dissimilarity. The subjects in the late group may have been as likely as subjects in the early group to establish new representations for word-final English consonants that lacked a phonetic counterpart in Italian. However, they might have been less likely than subjects in the early group to establish new representations for word-initial consonants that differed slightly in phonetic terms from an Italian counterpart (e.g. the aspirated English /p t k/ tokens examined here). This is what one might expect if L1 categories, as they develop, become more likely to assimilate their L2 phonetic counterparts.

The results of this study supported the hypothesis that amount of L1 use affects the identification of L2 consonants. To evaluate the effect of L1 use, we compared the subjects in the early group to a group of early bilinguals who reported using Italian seldom (designated early-low). The subjects in the early group made more errors than did the NE subjects identifying both initial and final consonants, whereas the subjects in the early-low group did not differ significantly from the NE subjects in either instance. The subjects in the early group made more errors identifying final but not initial consonants than the subjects in the early-low group did. These findings suggest that the conclusions drawn from a recent study of early bilinguals by Sebastián-Gallés and Soto-Faraco [1999, p. 120], may be too strong. These authors suggested that there are 'severe limitations to the malleability of the initially acquired L1 phonemic categories, even under conditions of early and extensive exposure', and that there are 'very strong constraints' on even early bilinguals' 'acquisition of phonemic categories' because L1 acquisition 'modifies the speech perception system'.

Our results suggest that if the L1 remains strong and active, it will influence the identification of at least some phonetic segments in an L2, even if the L2 is learned in childhood. However, the influence of the L1 phonetic system on the perception of L2 phonetic segments may be attenuated if the L1 is used relatively little. The findings obtained here for consonant identification are analogous to recent findings examining the overall pronunciation of an L2 [e.g. Flege et al., 1997b]. If examined closely, many early bilinguals are found to speak their L2 with a detectable foreign accent. However, the foreign accents of early bilinguals who continue to use their L1 often are stronger than those of early bilinguals who seldom use their L1.

The groups of early bilinguals who differed in amount of L1 use also showed different effects of word position. The subjects in the NE and early-low groups made significantly more errors identifying consonants found in word-initial than in word-final position, whereas the subjects in the early group showed a trend in the opposite direction. The basis for the interaction between word position and L1 use is uncertain. For one thing, the word position effect observed here for the NE and early-low subjects agrees with the results of some previous studies [Wang and Bilger, 1973; Bilger and Wang, 1976; Helfer, 1994] but not others [e.g. Dubno and Levitt, 1981; Gelfand et al., 1985; Redford and Diehl, 1999]. The divergence between previous studies may be due to a difference in the range of consonants presented and the range of possible response altematives. Whatever the basis, it appears that the word-final English consonants examined in this study were more identifiable than the word-initial consonants for the NE speakers and the early bilinguals who used Italian seldom (early-low). But why did the same not hold true for the early bilinguals who continued to use Italian often?

We speculate that the early bilinguals who continued to use Italian often (early) had a more 'Italian-like' mode of syllable processing than the early bilinguals who seldom used Italian (early-low). It is common for Italian words to be made up of CV syllables (e.g. *cinema, bucato*). Given that fewer Italian than English words end in a consonant [Carlson et al., 1985], Italian monolinguals might allocate relatively less attention to information signaling consonant identity at the end of words than English monolinguals do. If this is so and if L1 processing strategies transfer to an L2, then subjects in the early group may have identified word-final English consonants less accurately than subjects in the early-low group did because they were more likely to use an 'Italian' mode of syllable processing.

The tentative interpretation just offered as to why the early and early-low groups differed is reminiscent of a finding by Cutler et al. [1983]. These authors examined the amount of time early bilinguals needed to determine whether or not a visually defined target syllable (e.g. 'ba' or 'bal') had occurred in auditorily presented 2-syllable and 3-syllable words. An analysis of reaction times led the authors to conclude that French-dominant bilinguals were more flexible than English-dominant bilinguals were. (Only the French-dominant bilinguals showed sensitivity to the same subsyllabic units as French monolinguals did when responding to French words.) Of course, the two groups of early bilinguals in this study are not readily comparable to the two groups examined by Cutler et al. [1983]. In the Cutler et al. [1983] study, language 'dominance' was defined on the basis of the subjects' response to a single question. In the present study, the two early bilingual groups were defined on the basis of self-reported use of Italian. Also, we attribute the word position effect observed here to an attention mechanism arising from the relative infrequency of word-final consonants in the L1 compared to the L2. The effect observed by Gutler et al. [1983], on the other hand, was attributed to cross-language differences in syllable markedness and syllabification.

The final question addressed here was whether individual differences in PSTM would affect the native Italian subjects' ability to identify English consonants. PSTM was assessed by having the subjects repeat nonwords (formed from Italian CV syllables) that were presented in the quiet. PSTM has been linked to aspects of both L1 learning [Gathercole and Baddeley, 1993] and L2 learning [Service, 1992; Service and Kohonen, 1995; Dufva and Voeten, 1999]. The nonword repetition scores obtained for the native Italian subjects accounted for a significant amount of variance in the word-

initial and word-final consonant identification scores (8 and 15%, respectively) after the effects of other variables were removed.

This finding may provide a useful starting point for understanding the large inter-subject differences that one often sees in L2 speech studies [e.g. Bradlow et al., 1997]. We speculate that the repetition of nonwords – and so individual differences in PSTM – may tap skills needed to establish long-term memory representations for phonetic segments. More specifically, an aptitude for holding strings of CV syllables in short-term memory prior to reproducing them may aid in the development of long-term memory representations for L2 consonants. The native Italian subjects who possessed this aptitude to a high degree may have been better able to establish phonetic categories for English consonants than those who possessed it to a lesser degree. The nonword repetition scores may have accounted for somewhat more variance in the final than initial consonant error scores, because the native Italian subjects needed to create more new representations for word-final than word-initial English consonants (table 1).

In summary, this study examined the role of AOA and amount of L1 use on native Italian subjects' identification of English consonants. Both AOA and L1 use affected performance. The results suggested that a nativelike identification of L2 consonants can be achieved only if L2 learning begins early in life and the L1 is used relatively seldom. This study provided preliminary evidence that individual differences in PSTM may influence the perception of L2 consonants, perhaps by affecting the adequacy of long-term memory representations that are developed for L2 consonants. However, more work will be needed to prove or disprove this hypothesis.

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