Early and Late Bilinguals' Vowel Perception and Production: English Vowel Contrasts that Give Serbian-English Bilinguals a H(E)AD-ache

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1. Introduction

Adults learning a second language (L2) ("late learners") have difficulty achieving a native speaker's level of accuracy in both perception and production of L2 phonetic segments. This difficulty often results in deviant production of L2 segments that is perceived as accented speech by native speakers of that language. It is generally agreed that this failure in nonnative segmental production and perception is caused by previous linguistic experience with the first (L1) language. Late learners are expected to show stronger L1 effects than learners who learnt their L2 in early childhood ("early learners") (MacKay, Flege, Piske, & Schirru, 2001; Piske, Flege, MacKay, & Meador, 2002).

However, not all L2 phonetic segments are equally difficult for late learners. The learnability of L2 phonetic segments is perceptual in nature and depends on the perceived phonetic distance between them and the acoustically, phonetically and articulatorily most similar segment(s) in the learner's L1 phonetic inventory. It is generally assumed that certain L2 segments will be perceptually related or assimilated to the most similar L1 segment(s) even if there is a detectable acoustic difference between them (C. T. Best, McRoberts, & Sithole, 1988). This perceived distance between L1 and L2 segments plays a crucial role in two models of speech perception: the Perceptual Assimilation Model (PAM)(C.T. Best, 1994, 1995) and the Speech Learning Model (SLM)(Flege, 1995). According to both models the degree of success a listener will have in perceiving a non-native segment depends on perceived similarities and dissimilarities between phonetic elements of their L1 and L2. According to PAM, this relationship is based on resemblance of articulatory properties used in articulation of these segments (e.g., constriction locations, active articulators or degree of constrictions). These articulatory properties are essential for perceptual assimilation of nonnative segments into native segments. PAM accounts for perception of non-native contrasts, not only for the individual segments. When two members of a non-native contrast are perceived as equally good instances of a single native category (single category assimilation or SC), their discrimination will be relatively difficult. When one member of a non-native contrast is perceived as a better instance of a native category than the other (category goodness or CG), their discrimination will be relatively easy. Those non-native categories that are mapped onto two different L1 categories (two category assimilation or TC) will be discriminated easily. PAM does not propose any AOL specific difference in non-native segments discrimination regarding the AOL. On the other hand, SLM addresses the questions of L2 learning and focuses on highly experienced bilinguals. That model proposes that adults learning an L2 use equivalence classification to relate non-native segments to their L1 segments. Late learners of an L2 will be less successful in learning L2 segments that are perceived as "similar" to L1 segments even if they acoustically differ from each other. For such "similar" L2 segments new phonetic category formation will be blocked by the perceptual mechanism of equivalence classification. Late learners will eventually establish new categories for L2 segments that are perceived as distant ("different") from any L1 segment. This perceived phonetic distance between L2 and L1 segments is the essential condition for an L2 category to be established. Early learners are not expected to have

difficulties acquiring either "similar" or "different" segments. SLM does not take into account a specific position regarding how cross-language phonetic distance is assessed.

Listeners' response patterns for non-native contrasts depends also on phonetic context (Lively, Logan, & Pisoni, 1993) and different cognitive demands in different testing conditions (Werker, 1984; Werker & Logan, 1985). Werker and Logan (1985) have shown that variations in interstimulus interval (ISI) facilitate or constrain sensitivity to non-native phonetic distinctions, with listeners demonstrating a phonetic level of processing when the ISI is 500 msec and a phonemic (phonological) level of processing when the ISI is 1500 msec.

The main hypotheses of this study derive from the predictions based on PAM and SLM that certain non-native contrasts will be difficult to discriminate by late learners of an L2. Discriminability of a non-native contrast is predicted by its assimilation pattern to one or more native categories. Furthermore, accuracy in perception of non-native segments is related to accuracy in production of these segments.

Production and perception of two Australia English (AusE) vowel contrasts /æ/-/ɛ/ and /ɪ/-/i /, by Serbian-English bilinguals differing in age of learning Australian English as a second language, were tested. Production accuracy was assessed using auditory judgment of native monolingual speakers of Australian English. Perception was tested in assimilation and discrimination tasks.

The Serbian vowel inventory consists of five short (/a/, /e/, /i/, /o/, /u/) and five long (/a:/, /e:/, /i:/, /o:/, /u:/) vowels. Predictions based on SLM and PAM led to different expectations. According to the SLM, late Serbian-English bilinguals will perceive vowels from Australian English /ɪ /- /i/ contrast as "similar" to Serbian /i/ and produce them less accurately than /æ/-/ɛ/ contrasting vowels, which will both be perceived as dissimilar ("new") from any Serbian category. These predictions were based on F1, F2 and F3 values of Serbian /a/, /e/, /i/ and /i:/ and English /æ/, /ɛ/, /ɪ /, /i/ at the acoustic midpoint of the vowel.

However, according to PAM, vowels from the English contrast /ɪ /- /i / will be perceptually assimilated to two distinct Serbian vowels /i/ and /i:/ (TC assimilation). Similarly, the /æ/-/ɛ/ contrast will be perceptually assimilated to Serbian /a/ and /e/ (TC assimilation).

Experiment 1 consisted of a production task and perception task (AXB discrimination and perceptual assimilation with goodness-of-fit ratings). Experiment 2 consisted of AX discrimination and perceptual assimilation with ratings. In addition, the interstimulus interval was manipulated and the priming paradigm from lexical decision tasks (Slowiaczek & Hamburger, 1992; Slowiaczek, Nusbaum, & Pisoni, 1987) was adopted to test whether listeners exploit the phonological relation between the prime and the target to improve their performance in certain conditions. Primes were phonologically identical, phonetically similar and unrelated to the target, and were presented with 500 and 1000 msec ISIs.

2. General method

2.1 Participants

The participants in both experiments were 30 Serbian-English bilinguals differing in age of learning (AOL) of Australian English. The participants reported a limited exposure to English in classroom settings and through music and films, but were unable to speak or understand spoken English before immigrating to Australia. "Early learners" (EL) had learnt English before the age of 5 years, "late learners" (LL) had learnt English after the age of 18. There were 15 participants in each group. 15 monolingual (M) Australian English (AusE) speakers were included as a control group in the production and perceptual discrimination experiments. None of the participants who had participated in Experiment 1 participated in Experiment 2.

The mean age of the participants in Experiment 1 was 27.8 (EL), 33.5 (LL) and 21.8 (M). The mean age of the participants in Experiment 2 was 28 (EL), 32.9 (LL) and 22.9 (M) years.

2.2 Design

The independent variables in the production and discrimination experiments were age of learning (AOL) with two levels of measurement (EL and LL) and English vowel contrast with two levels of measurement (EVC) (/æ/-/ɛ/ (EVC1) and /ɪ /- /i/ (EVC2). An additional independent variable in the production experiment was the identified vowel category (IDC) (IDC1: /æ/, /ɛ/ and IDC2: /ɪ/, /i/). Dependent variables in production and discrimination experiments was percentage of accurate production and discrimination scores. In perceptual assimilation experiments an additional independent variable was Serbian vowel contrast (SVC) with two levels (SVC1: /a/-/e/ and SVC 2: /i/ - /i:/) and the dependent variable was a percentage of identified Serbian vowels .

In the priming experiments an additional independent variable was a prime (P) with two levels: identical prime (IP) and similar prime (SP).

2.3 Stimuli

Vowels /æ/, /ɛ/, /ɪ / and /i / were produced in h_d frame (*had, head, heed, hid*) in sentences *H_d is the next word to say. I say h_d again. H_d* by ten male monolingual speakers of Australian English. These sentences were repeated ten times for each vowel. The recorded speech material was digitised at 44kHz sing Cool Edit. Three tokens in citation form for each vowel were chosen from three different speakers and used as stimuli. The vowels in the chosen tokens were closely matched in duration, F0, and F1, F2, and F3 at the vowel midpoint. This way we generated 36 stimuli (4 vowels x 3 speakers x 3 tokens). Amplitude of each word was normalized to 90% of the peak mean intensity of all words and stored in separate files per word.

3. Experiment 1: Perception and production of /æ/-/ɛ/ and /ɪ/-/i/ contrasts

3.1 Experiment 1a: Production

3.1.1 Procedure

The Serbian-English bilinguals and native English monolinguals repeated the targeted English vowel in h_d frame (*had, head, hid*, and *heed*) after hearing it in a carrier sentence *"_____is the next word to say"* produced by three male monolingual speakers of Australian English. There were 108 trials (4 vowels x 3 speakers x 3 tokens x 3 repetitions). Recorded pronunciation of these words was digitised at 44.1 kHz. Three best recordings for each vowel per speaker were presented to 10 native monolingual Australian English speakers for identification. They were instructed to identify each vowel using one of the following keywords given on the computer screen: *heed, hid, head, had, hard, hut, hot horde, hood, heard.*

3.1.2 Results and discussion

Percent correctly identified vowels by native AusE listeners was averaged for each participant and then each group's mean score was derived from these values. These results are presented in Figure 1. Two planned comparison ANOVAs were conducted separately for each EVC.

There was a significant interaction between AOL (EL vs. LL) x IDC1 (/æ/ vs. /ɛ/) x EVC1 (/æ/-/ɛ/): $F(1,9) = 660.22$, $p < 0.05$. The planned comparison of AOL (EL vs, LL) and IDC2 (/i/ vs. /ɪ/) for EVC 2 (/i/-/ɪ/) was not statistically significant. When early learners were compared to the monolingual control group there was no significant interaction with IDC for either EVCs.

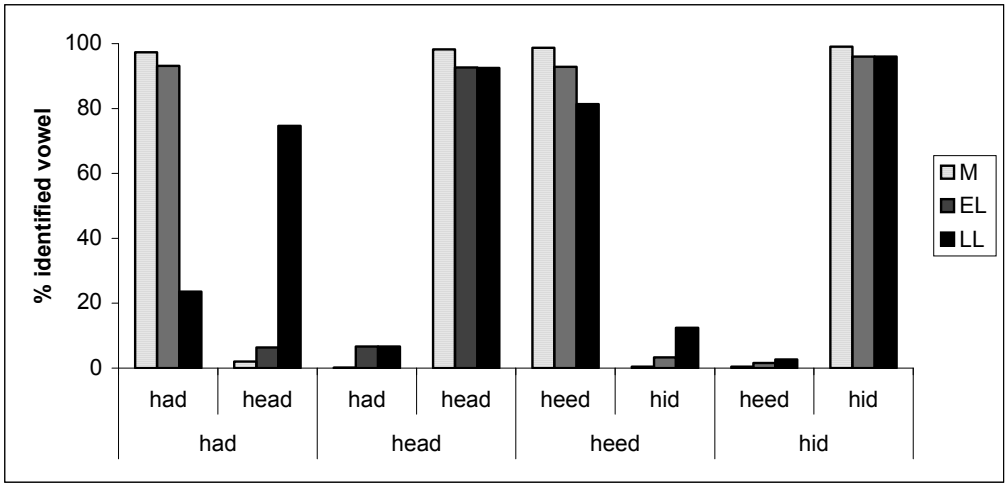

Figure 1. Production of English *had, head, hid* and *heed* by early and late Serbian-English bilinguals and English monolinguals. On the x-axis AusE target words (bottom line) and the judgments on the Serbian-English bilinguals' production (top line) are presented. The percentage of identified productions is presented on the y-axis.

It was hypothesized, based on the SLM, that perceived similarity between the English /ɪ/- /i/ contrast and Serbian /i/ would prevent late Serbian-English bilinguals from establishing new categories for these two vowels. On the other hand, late bilinguals were expected to have no difficulties producing the English /æ/-/ɛ/ contrast, as both members of this contrast are perceived as dissimilar ("new") from any Serbian vowel.

The production results revealed the opposite: late bilinguals failed to establish separate categories for the /æ/ - /ɛ/ contrast, substituting both /æ/ and /ɛ/ with /ɛ/ but conversely did establish separate categories for the /ɪ/ - /i/ contrast. Early learners produced both contrasts accurately.

3.2 Experiment 1b: Perceptual assimilation and rating

3.2.1 Procedure

The aim of this experiment was to determine the perceptual relationship between the English /æ/ - /ɛ/ and /ɪ /- /i / contrasts and Serbian vowels. The experiment consisted of two parts: in the first part listeners were asked to choose a Serbian word or nonword that contained the same vowel as the English word they heard. The possible responses were all Serbian vowels, long and short, embedded in the b_ba frame. Since the length is not orthographically represented in Serbian, a double orthographic representation of a short vowel was used to indicate the Serbian word with the same vowel differing in length. The possible responses were: *baba, beba, biba, buba, boba* (the key words with the short vowels) *and baaba, beeba, biiba, buuba, booba* (the keywords with the long vowels). In the second part participants were asked to rate the similarity between the English and Serbian vowel using a 7-point scale ("1"-

very little similarity between them, "7"- exactly the same vowels). There were 108 randomly presented trials (4 vowels x 3 speakers x 3 tokens x 3 repetitions).

3.2.2 Results and discussion

Percent chosen Serbian keywords given in response to the English words was averaged for each participant and then each group's mean score was derived from these values. Only the keywords that were chosen more than 50% of the time (*baba, beba, biba* and *biiba*) were taken into analysis. A planned contrast ANOVA for each of the two English contrasts was conducted. There was a significant three way interaction between AOL (E vs. L) x SVC1 (/a/ vs. /e/) x EVC1 (/æ/-/ɛ/): $F(1,28) = 50.94$, $p < 0.05$. Early learners' response to English *had* was *baba*, for *head* was *beba*. Late learners' response to both *had* and *head* was *beba.* Planned comparisons of AOL (EL vs. LL) and SVC2 (/i/ vs. /ɪ:/) for EVC 2 (/i/-/ɪ/) was not statistically significant. Both groups' response to English *hid* was *biba*, and to English *heed* was *biiba*.

Mean goodness-of-fit ratings for each vowel were submitted to independent t-tests analysis with the aim of assessing how Serbian speakers of Australian English perceptually assimilate the two vowel contrasts to their native categories. Despite the different assimilation patterns, for both groups English /ɛ/ is a better instance of a chosen Serbian vowel than English /æ/. Early learners perceptually assimilated English /æ/ to Serbian /a/ with mean goodness-of-fit rating 2.97 and English /ɛ/ to Serbian /e/ with mean goodness-of-fit rating 4.40. The difference between ratings was significant, $t(14) = 20.574$, $p < 0.05$. Late learners perceptually assimilated both /æ/ and /ɛ/ to Serbian /e/ with mean goodness-of-fit ratings 2.85 and 4.29, respectively. The difference between these ratings was also significant: $t(14) = 55.443$, $p < 0.05$.

Early learners perceptually assimilate each member of English /æ/-/ɛ/ contrast to two different (/a/ and /e/) Serbian categories (TC assimilation). Late learners perceptually assimilate both /æ/ and /ɛ/ to a single Serbian category (/e/), but not as equally good examples of that category (CG assimilation).

Perceptual assimilation patterns for the /ɪ /- /i/ segments were identical for both groups: the vowels were perceived as instances of Serbian /i/ and /i:/, respectively (TC assimilation) , with /ɪ/ being a better match to /i/: $t(14) = 18.95$, $p < 0.05$ and $t(14) = 18.49$, $p < 0.05$ than /i/was to /i:/.

According to PAM, pairs of non-native sounds that are perceptually related to native categories as TC or CG assimilation, will be easy (TC) or relatively easy (CG) to discriminate. It was expected that both groups would demonstrate excellent discrimination of the /ɪ /- /i/ contrast. For the /æ/-/ɛ/ contrast it was expected that early learners would demonstrate excellent, and late learners relatively good discrimination. These predictions were tested in Experiment 1c.

3.3 Experiment 1c: Perceptual discrimination

3.3.1 Procedure

Serbian-English bilinguals' discrimination of /æ/-/ɛ/ and /ɪ/- /i/ contrasts was tested in an AXB discrimination task.

In each trial participants were presented with three physically different tokens from one vowel contrast and were asked to determine whether the second token (X) was the same as the first token (A) or the third token (B). A and B were always contrasting vowels. Each contrast was tested with both vowels from the contrast in each position: AAB, ABB, BBA,

BAA. The interstimulus interval (ISI) for all trials was 1000 ms. There were 324 trials (4 vowels x 3 speakers x 3 tokens x 9 repetitions in different positions).

3.3.2 Results and discussion

Percent correct discrimination was averaged for each participant and then each group's mean score was derived from these values. These results are presented in Figure 2. A planned comparison revealed a significant interaction among AOL (EL vs. LL) x EVC (EVC1 vs. EVC2):F(1, 42) = 285.78 and no significant interaction for the comparison between early learners and the monolingual control group. Late learners had difficulties discriminating the /æ/-/ɛ/ contrast but had no discrimination difficulties with the /i/ - /ɪ/ contrast:the main effect of EVC (EVC1 vs. EVC2) was significant: t (14) = 24.17 $p < 0.05$).

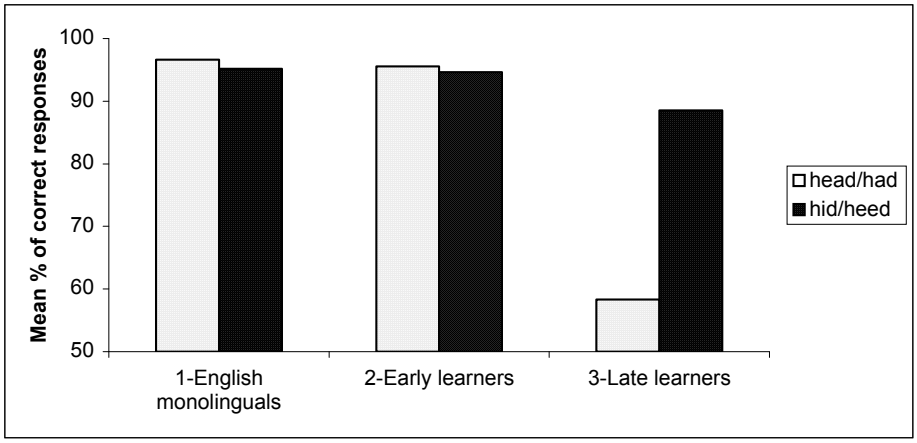

Figure 2. Serbian-English bilinguals' and English monolinguals' discrimination of /æ/-/ɛ/ and /ɪ /- /i / contrasts.

Given that late bilinguals perceptually assimilated /æ/ and /ɛ/ to a single native category differing in their similarity to that category (CG assimilation), poor discrimination performance on this contrast is surprising. When an English vowel contrast was assimilated as TC assimilation type, as in the case of the /ɪ /- /i/ contrast for both groups and the /æ/-/ɛ/ contrast for early learners, discrimination was good as expected, according to PAM.

4. Experiment 2: Phonologically primed perception of /æ/-/ɛ/ and /ɪ/- /i/ contrasts

In Experiment 2 a priming paradigm with 500 and 1000 ms ISI was used to further test Serbian-English bilinguals' sensitivity to phonetic and phonemic (phonological) levels of processing. It was expected that the 500 ms ISI would facilitate late learners' discrimination of the /æ/-/ɛ/ contrast in the identical condition, and inhibit discrimination that contrast in the similar condition. Early learners were not expected to differ from monolinguals in discrimination of the /æ/-/ɛ/ contrast. With the 1000 ms ISI late learners were expected to have difficulties in discrimination of the /æ/-/ɛ/ contrast in both similar and identical conditions. Early and late learners were also expected to demonstrate different assimilation patterns for the /æ/-/ɛ/ contrast. No difference between early and late learners was expected for the /ɪ /- /i / contrast.

4.1 Experiment 2a: Perceptual assimilation

4.1.1 Procedure

Participants were presented with a vowel embedded in a b_p context to which no response was required (a prime) and a vowel in h_d context to which response was required (a target). The vowels in the prime and in the target were the same in the identical condition (e.g., bæp / hæd; bɛp / hɛd; bip / hid; bɪp / hɪd), opposite members of the vowel contrast in the similar condition (e.g., bæp / hɛd; bɛp / hæd; bip / hɪd; bɪp / hid) and unrelated in unrelated condition(e.g., bup / hid; bup / hɪd; bop / hæd ; bop / hɛd). The same, similar and unrelated trials were randomly presented within 500 ms and 1000 ms ISI blocks. There were 216 trials (4 vowels x 3 speakers x 3 tokens x 2 repetitions x 3 conditions). The participants were told to ignore the prime and make a judgment on the target. The requested target judgment was the same as in the Experiment 1b.

4.1.2 Results and discussion

Results from the 500 and the 1000 ms ISI condition were analysed independently. ANOVAs were conducted separately for the two EVC conditions within each priming condition. The mean percent of chosen Serbian keywords given in response to the English words for each group in the similar and the identical priming condition was subtracted from the unrelated (baseline) condition in order to assess the effect of identical and similar primes on perception of two English vowel contrasts.

In the 500 ms ISI condition a significant interaction was observed only for the similar prime condition between early and late learners for the /æ/-/ɛ/ contrast: AOL (EL vs. LL) x SVC1 (/a/ vs. /e/) x EVC1 (/æ/-/ɛ/), $F(1,28) = 21.42$, $p < 0.05$.

Although only responses given more than 50% of the time for the targeted English vowel were included in this analysis, it is important to note that early learners chose the Serbian keyword baaba 44% of the time, indicating that English /æ/ was perceptually assimilated to both Serbian /a/ and /a:/ with no significant difference between the mean rating scores for similarity between English /æ/ and Serbian /a/ (3.38) versus English /æ/ and Serbian /a:/ (4.30).

The assimilation patterns in both priming conditions with 1000ms ISIs for both English contrasts mirrored those obtained in Experiment 1b.

4.2 Experiment 2b: Perceptual discrimination

4.2.1 Procedure

Serbian-English bilinguals' discrimination of English /æ/-/ɛ / and /ɪ /- /i / contrasts were tested in the AX task preceded by a prime. In the identical condition the vowel in the prime and the vowel in the first target token were phonologically identical (e.g., bæp/ hæd/ hæd; bæp / hæd / hɛd; bip / hid / hid; bip / hid/ hɪd; etc). In the similar condition the vowel in the prime and the vowel in the first target token were opposite members of the same vowel contrast, that is, they were phonetically similar, differing in a single vowel feature (e.g., bæp / hɛd / hæd; bip / hɪd / hid, etc.). In the different condition the vowel in the prime and in the vowel in the target were acoustically and articulatorily unrelated (e.g., bup / hid /hid; bup/ hid/ hɪd; bop/ hæd/ hɛd, etc.). There were 432 trials (4 vowels x 3 speakers x 3 tokens x 4 repetitions x 3 conditions).Participants were instructed to ignore the first word they heard, and to decide whether the third and the second were the same or different words. Same, similar and

different priming conditions were presented in random order within fixed 500 ms and 1000 ms ISI blocks.

4.2.2 Results and discussion

The groups' d' discrimination scores for identical and similar conditions were subtracted from the unrelated (baseline) condition scores in order to assess how similar and identical prime affect perceptual discrimination. Results from the 500 and the 1000 ms ISI condition were analysed independently. Two planned comparisons between early and late learners and between early learners and monolinguals were conducted. Discrimination scores for the 500 ms ISI condition are presented in Figure 3.

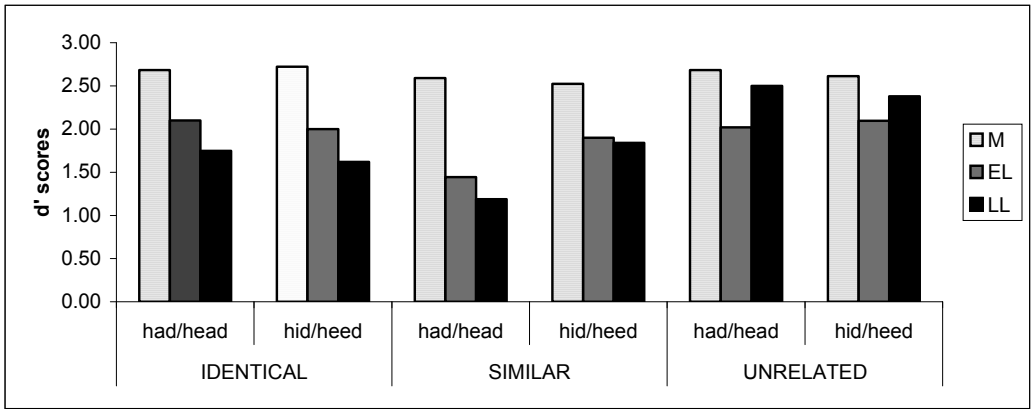

Figure 3. Serbian-English bilinguals' and English monolinguals' discrimination of /æ/-/ɛ/ and /ɪ /- /i / contrasts (500 ms ISI)

For the short, phonetic-level ISI condition of 500 ms there was a significant interaction of AOL (M vs. EL) x EVC (EVC1 vs. EVC2) x P (IP vs. SP): $F(1, 42) = 5.879$, $p < 0.05$. Early learners' discrimination of the /æ/-/ɛ/ contrast in the similar priming condition was poorer than monolinguals'. On the other hand, there was no significant difference between early and late learners, indicating that in the similar condition early learners have difficulties discriminating between /æ/-/ɛ/ just as the late learners did for all previous experiments.

Discrimination results in the 1000 ms ISI condition are presented in Figure 4. A significant interaction observed between early and late learners (AOL (LL vs. EL) x EVC (EVC1 vs. EVC2) x P (IP vs. SP) ($F(1, 42) = 15.84$, $p < 0.05$) revealed that late learners have difficulties discriminating the /æ/-/ɛ/ contrast in the similar priming condition. However, in the 1000 ms ISI condition the performance of early learners did not differ from that of monolingual speakers.

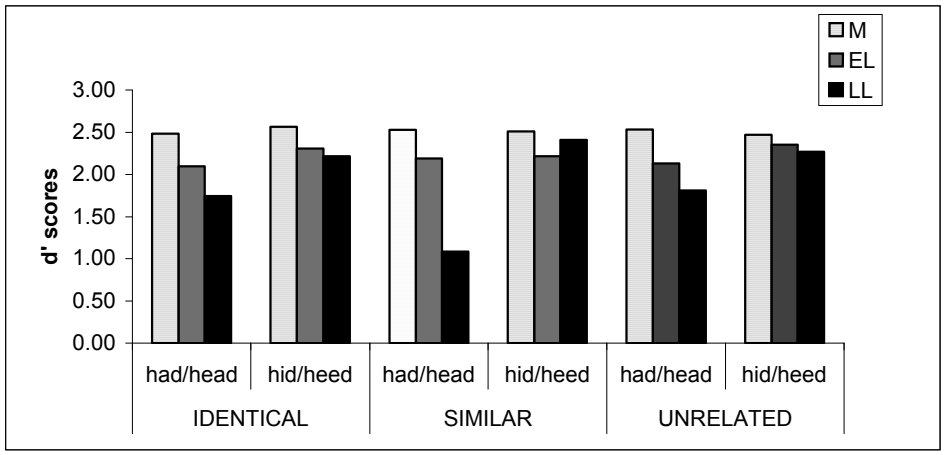

Figure 4. Serbian-English bilinguals' and English monolinguals' discrimination of /æ/-/ɛ/ and /ɪ /- /i / contrasts (1000 ms ISI)

5. General discussion

In this study, we tested the production and perception of two Australian English vowel contrasts /æ/-/ɛ/ and /ɪ /- /i / by Serbian-English bilinguals differing in the age of learning Australian English as a second language. Both production and perception results revealed that the /æ/-/ɛ/ contrast is difficult for late Serbian-English bilinguals, and in some testing conditions also for early Serbian-English bilinguals.

A hypothesis based on the Speech Learning Model (SLM; Flege, 1995) was that late Serbian-English bilinguals would establish new L2 phonetic categories for both vowels in the /æ/-/ɛ/ contrast and fail to establish new categories for either vowel in the /ɪ /- /i/ contrast. English /æ/ and /ɛ/ were expected to be perceived as different from both Serbian vowels and therefore relatively easy to acquire . English /ɪ /and /i/ were expected to be perceived as "similar" to Serbian /i/. This perceived similarity, according to SLM, activates an equivalence classification mechanism and blocks a new category formation. These hypotheses were not supported.

We assessed the perceived distance between the tested English vowels and the closest Serbian vowels in perceptual assimilation and discrimination tasks. The predictions based on PAM (Best, 1994, 1995) were that the vowels from the /ɪ/- /i/contrast would be perceptually assimilated to two distinct Serbian categories /i/ and /i:/ (TC assimilation) and easy to discriminate. Vowels from the /æ/ -/ɛ/ contrast would be perceptually assimilated to the Serbian /a/ and /e/ (TC assimilation) and also easy to discriminate. PAM does not specify any predictions regarding the age of L2 learning. However, the results of these experiments revealed different assimilation patterns for the late and early Serbian-English bilinguals for the /æ/ -/ɛ/ contrast. Early bilinguals displayed the predicted TC perceptual assimilation, while late learners perceived both members of /æ/ -/ɛ/ as instances of a single Serbian category /e/ (CG assimilation).

Both groups of bilinguals perceptually assimilated the vowels from the /ɪ/- /i/ contrast as instances of Serbian /i/ and /i:/ (TC assimilation). The perceptual assimilation pattern was a reliable predictor of discrimination accuracy when this non-native contrast was perceived as a TC assimilation. However, a surprising finding was the poor discrimination of /æ/ - /ɛ/ contrast by late learners. According to PAM, discrimination of a CG assimilated contrast should be relatively easy. It seems that in the AXB task late learners were not able to make

use of the distinction they perceived when these vowels were presented in the assimilation and rating task.

Serbian-English bilinguals' sensitivity to the tested English contrasts was further explored in perceptual assimilation and discrimination experiments using a priming paradigm with 500 and 1000 ms ISIs. In phonetically similar prime-target pairs with 500 ms ISI, early bilinguals perceptually assimilated English /æ/ as Serbian /a/ less frequently than in the unrelated condition. Furthermore, a high percentage of Serbian /a:/ responses for English /æ/ indicates that in this testing condition early bilinguals became sensitive to temporal differences between /æ/ and /ɛ/ (Smiljanic & Bradlow, (in press)) which they were not able to perceive in other testing conditions. This finding seems to fall within the scope of Werker's (1984) and Werker and Logan's (1985) about the relationship between discrimination accuracy of a non-native contrast and ISI: in an AX task with 1500 ms ISI, listeners demonstrate phonemic level of processing, whereas when the ISI was shortened to 500 ms, listeners showed evidence of being sensitive to non-native phonetic distinctions. In addition, in the primed discrimination task with 500 ms ISI early Serbian-English bilinguals differed significantly from English monolinguals in both similar and identical conditions.

This finding suggests that the English /æ/ -/ɛ/ contrast is not fully established even in early learners. This instability is revealed when perceptual assimilation and discrimination of the /æ/ -/ɛ/ contrast is tested in the experimental condition that taps phonetic level of processing (500 ms ISI).

Taken together, these findings indicate that the discrimination and production accuracy of L2 learners reflect how listeners assimilate nonnative vowels to their native vowels. Differences in the assimilation patterns between early and late learners of an L2 reflect the difference in establishment of the L1 phonetic system at the time of L2 onset. Although the L1 phonetic system imposes a weaker influence on early learners' perception of the L2 segments, allowing them to produce and discriminate nonnative segments in a native-like way, the nonnative contrast that late learners fail to establish may not be fully established even in early learners of an L2.

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