

Investigating Catalan-Spanish bilingual EFL learners' over-reliance on duration: Vowel cue weighting and phonological short-term memory

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ABSTRACT

The aim of this study was to explore the relationship between phonological short-term memory (PSTM) and Catalan-Spanish learners' cue weighting of English /i:/-/ɪ/. A sub-goal was to assess possible long-term memory effects on serial nonword recognition (SNWR) as a measure of PSTM. Two 8-step continua were created (*feet-fit*) in which vowel duration was manipulated and presented in a two-alternative forced choice task. The participants' ($N=84$) PSTM capacity was measured using a SNWR task consisting of 144 monosyllabic nonwords presented in 24 pairs of sequences of increasing length (from 5 to 7 nonwords). The task was performed in three languages: L1 (Catalan), L2 (English) and Lx (Russian). Learners with high PSTM capacity categorized /i:/ and /ɪ/ in a more native-like manner than those with low PSTM capacity, who presented greater over-reliance on duration. While L1, L2 and Lx scores correlated significantly, ANOVAs revealed a significant main effect for language, suggesting that individual differences in PSTM were relatively language-independent despite the sensitivity of PSTM scores to testing language. Overall these results suggest that learners with higher PSTM may have an advantage over those with lower PSTM in making use of more "difficult" or less readily accessible cues in the categorization of L2 vowels.

KEYWORDS: Phonological short-term memory (PTSM), serial nonword recognition (SNWR), cue weighting, vowel categorization

1. Introduction

Cross-linguistic differences in cue weighting constitute a source of perceptual difficulty for L2 learners and may lead to the formation of inaccurate representations for L2 sounds that will in turn cause the presence of a foreign accent in L2 speech production at the segmental level (Flege 1995; Iverson and Kuhl 1995; Ylinen et al. 2010). For example, while native English speakers categorize tense-lax vowel contrasts by integrating durational and spectral information and rely mainly on vowel quality differences (Hillenbrand et al. 2000), Catalan-Spanish learners of English (CSLs) find it difficult to attend to both these cues in a native-like manner and rely mainly on vowel duration. A much investigated contrast in the literature is /i:/-/ɪ/, which poses a challenge to Spanish speakers of English, both in perception and production, because they assimilate these L2 vowels to the single native category /i/ (Flege 1991). Extensive research on Spanish and bilingual Catalan-

Spanish EFL learners' categorization of English /i:/ and /ɪ/ (Bohn 1995; Cebrian 2006, 2007; Cerviño-Povedano and Mora 2009; Escudero and Boersma 2004; Mora and Fullana 2007) has shown that they rely on vowel duration to a greater extent than native English speakers, despite the fact that duration is not a contrastive feature in either Catalan or Spanish. Bohn's (1995) Desensitization Hypothesis provides an explanation to this phenomenon by suggesting that when spectral cues are insufficient (due to desensitization), duration will be used regardless of whether it is contrastive or not in the L1.

PSTM is one of the components of working memory (WM) within Baddeley and Hitch's (1974) multi-component WM model. WM is divided into two main information stores, the phonological loop and the visual-spatial sketchpad, which control the verbal and visual-spatial domains respectively. The phonological loop is responsible for the storage of verbal information over short periods of time and it is formed by a short-term phonological store and an articulatory rehearsal component (Baddeley 1986, 2003; Baddeley and Hitch 1974). The auditory input reaching the short-term phonological store is subject to decay within approximately two seconds, unless refreshed through sub-vocal rehearsal in the articulatory rehearsal component. Previous research has shown that PSTM capacity is related to language acquisition in children in areas such as vocabulary, syntax, semantics and oral fluency (Adams et al. 1999; Adams and Gathercole 1996, 2000; Blake et al. 1994; Dufva and Voeten 1999; French 2006; Gathercole et al. 1997). More recently, PSTM has been shown to significantly predict children's L2 grammar development and vocabulary knowledge (French and O'Brien 2008). However, at present little is known about the role of PSTM in adults' L2 acquisition. Studies looking into this issue in formal and immersion learning contexts have shown that PSTM makes an important contribution to the development of adults' L2 oral fluency (O'Brien et al. 2006, 2007), but the relationship between PSTM and L2 speech learning remains largely under-researched.

PSTM is commonly measured by tasks such as nonword repetition (NWR), serial nonword recognition (SNWR), immediate serial recall and the digit span test. Most typically, PSTM has been measured by NWR tasks. Although the reliability of these measures has been called into question on the grounds that PSTM task performance could be directly influenced by linguistic knowledge (Ottem et al. 2007), the results of a recent study suggest that NWR discriminates among subjects' level of PSTM capacity irrespective of the language of the nonwords (French and O'Brien 2008). Thus, whereas existing linguistic knowledge in long-term memory (LTM) may enhance PSTM function by facilitating phonological encoding, it does not directly influence the quality of the temporary storage in itself (Gathercole 2006). In keeping with this view, the storage capacity of short-term memory may be considered to be language-independent, implying that PSTM ability does not change during young adulthood (O'Brien et al. 2007).

The goal of the present study was to explore the relationship between PSTM and L2 phonological acquisition by adults. Studies investigating PSTM and adults' SLA are scarce and, to the best of our knowledge, only one study (MacKay et al. 2001) has examined the role that PSTM might play in adults' L2 phonological acquisition. This study investigated Italian native speakers' perception of English consonants in noise. PSTM, assessed through a NWR task, accounted for a considerably large amount of inter-subject variability in the identification of L2 English consonants, independently explaining 15% of the variance in subjects' errors identifying word-final English consonants, and 8% of variance for word-initial consonants. The present study investigates the effect of possible differences in PSTM, as measured by a SNWR task, on CSLs' categorization of English /i:/ and /ɪ/. We hypothesized, on the basis of previous research (Bohn 1995; Cebrian 2006, 2007; Cerviño-Povedano and Mora 2009; Escudero and Boersma 2004; Mora and Fullana 2007) that CSLs would make use of duration cues to a greater extent than native English speakers (NSs). In addition, given the body of evidence relating PSTM to language development in other linguistic domains, learners with higher PSTM capacity were expected to process durational and spectral information of /i:/ and /ɪ/ in a more native-like manner, categorizing the members of this tense-lax contrast more accurately. Finally, this study also investigated the influence of linguistic knowledge on PSTM measures by having learners perform on three versions of the SNWR task in three languages: L1 (Catalan), L2 (English) and Lx (Russian). In accordance with previous research (Gathercole 2006; O'Brien et al. 2007), we hypothesized that the participants' performance would vary as a function of linguistic knowledge (Catalan > English > Russian), but the three sets of SNWR scores were also expected to be strongly correlated.

2. Method

2.1 Participants

The participants in this study were 84 Catalan-dominant Catalan-Spanish bilinguals enrolled in a degree in English Studies at the University of Barcelona (mean age= 21.5) selected from a larger pool of EFL learners on the basis of their linguistic profile. A group of 13 native speakers of Southern-British English (mean age= 40.2) provided base-line data for the vowel categorization task. The EFL learners, who were given course credit for participating in the experiments, completed a language background questionnaire and reported to have normal hearing and no speech-related dysfunctions.

2.2. Vowel categorization task

Cue weighting in the categorization of English /i:/ and /ɪ/ was assessed through a two-alternative forced choice task with words including these vowels (*feet* and *fit*, respectively). A male native speaker of Southern-British English was recorded producing 10 tokens of the words *feet* and *fit* embedded in the carrier phrase “I’ll say _____ again”. The mean duration for each vowel across tokens was found to be 101.2 ms. ($SD= 10.26$) for /i:/ and 54.7 ms. ($SD= 9.86$) ms for /ɪ/. After examining duration values recently reported in the literature for these vowels (Steinlen 2005), Praat (Boersma and Weenink 2007) was used to create two 8-step duration continua with 190 ms and 50 ms as duration endpoints. The tense vowel /i:/ was shortened and the lax vowel /ɪ/ was lengthened in 20 ms equidistant steps. The stimuli making up the two continua were aurally presented ten times each in fully randomized blocks. Upon hearing every stimulus once, the participants selected one response alternative displayed on the screen (*feet* or *fit*) by means of a mouse click and pressed a “next” button to hear the following stimulus. The participants were presented with a total of 160 stimuli in this task, which took them approximately 15 minutes to complete. Two measures of perceptual accuracy for the /i:/-/ɪ/ contrast were derived from the two-alternative forced choice task independently for every continuum: percent correct identification (ID) averaged across the 8 steps of each continuum, and a temporal effect score (TES) calculated by deducting the mean percent correct identification score of the first step from that of the last step for each continuum (Flege et al. 1997), which served as a measure of the size of the effect of the duration manipulation and therefore indicated the degree of reliance on duration in the perception of the /i:/-/ɪ/ contrast.

2.3. PSMT: Serial nonword recognition (SNWR)

PSTM was assessed through a SNWR task, which was chosen for two main reasons. Firstly, SNWR does not involve an articulation component that, due to articulatory demands, might hinder subjects’ performance and affect the reliability of the PSTM measure (Snowling et al. 1991). Secondly, SNWR has been shown to minimize the effects of lexical influences on phonological memory (Gathercole et al. 2001). Thus, as in previous studies (e.g. Isaacs and Trofimovich *in press*; O’Brien et al. 2006, 2007), SNWR was deemed to be a more accurate measure of PSTM than nonword recall or repetition. In this task, participants were asked to determine whether pairs of strings of nonwords increasing in length appeared in the same or in different order.

The SNWR task consisted of 24 pairs of CVC nonword sequences of increasing length (5, 6 and 7 nonwords). As a means to examine whether participants’ performance in the SNWR task might be influenced by linguistic knowledge, three versions of the same task in three languages were used: L1

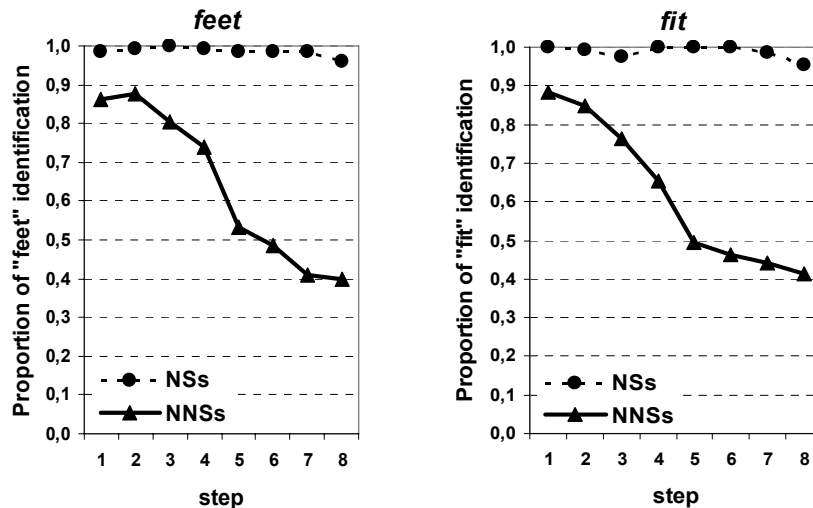
(Catalan), L2 (English) and Lx (Russian, which none of the participants had ever been exposed to). The nonwords were all CVC syllables conforming to the phonotactic regularities of each language. They were embedded in carrier phrases with similar intonational contours across languages, which elicited target nonwords in a falling tone context. None of the nonwords in any of the three languages produced or closely resembled a word in any of the other languages. They were read aloud at normal speed several times by female native speakers of Catalan, English and Russian and were digitally recorded (Marantz PMD660) in a sound-proof booth with a unidirectional dynamic microphone (Shure SM58). The recordings were digitized at a 44kHz sampling rate. The best tokens of each nonword were selected, segmented, edited and normalized for intensity (70dB) to minimize differences in loudness among stimuli. Each test consisted of 144 monosyllabic CVC nonwords, except for Russian, in which CVC words and nonwords were mixed indistinctively. The nonwords, separated by a 300 ms. silence, were presented in sequences of 5, 6 and 7 items so that all nonwords in a sequence would contain a different vowel and as many different consonants as possible. A given trial consisted of either two identical nonword sequences (e.g. *A, B, C, D, E*; a, b, c, d, e) or two nonword sequences that were identical except for two transposed items (*A, B, C, D, E*; a, b, **d**, **c**, e). Trials at each sequence length contained 4 same and 4 different nonword sequence pairs and were randomly presented with 1000 ms. delay upon response. In order to minimize the salience of the transposed items, the first and the last items in a sequence were never transposed. Additionally, a 4-trial practice block was included to familiarize participants with the task. The experiment was controlled by DmDx display software (Forster and Forster 2003). The task was explained both by the experimenters and also by written instructions that were displayed on the screen. The participants started the test with the practice trials, and the task began when they reported to have fully understood the procedure. The order of presentation of the Catalan, English and Russian versions of the SNWR task was counterbalanced across participants. This task, which lasted approximately 30 minutes, was done after the categorization task in the same data collection session. The number of correctly identified same and different sequences out of 24 (Isaacs and Trofimovich *in press*) and a weighted score (out of 144) that was obtained by assigning different points to every correctly identified sequence according to sequence length, i.e. 5, 6 and 7 points, respectively (O'Brien et. al 2007) were used as measures of PSTM capacity.

3. Results and discussion

The results of the two-alternative forced choice task revealed, as expected, that CSLs over-relied on duration as opposed to the group of NSs who were insensitive to the duration manipulation (see Figure 1). The shorter the duration of

the tense vowel /i:/ (*feet*), the more often it was identified as /ɪ/ (*fit*), and the longer the duration of the lax vowel /ɪ/ (*fit*), the more often it was identified as /i:/ (*feet*). These ID scores were submitted to a repeated measures ANOVAs, yielding a significant main effect of duration manipulation along the continuum ($F(7, 77)=16.6$; $p<.001$ for both continua). Further Bonferroni-adjusted pairwise comparisons showed that a two-step (40 ms) difference produced a significant effect on vowel categorization ($p<.001$ for all comparisons). NSs were found to be insensitive to the duration manipulation in the stimuli, as they relied on vowel quality differences. Because the CSLs group obtained slightly different mean percent correct identification scores for the two continua, 63.27 ($SD=27.07$) for *feet* vs. 61.07 ($SD=27.40$) for *fit*, and this difference approached significance ($t(83)=1.87$, $p=.065$), we did not obtain an overall mean for both continua. The analysis of the relationship between PSTM and perceptual accuracy was therefore conducted independently for the two continua.

Figure 1: Duration manipulation effect on the perception of the *feet* and *fit* continua.



The hypothesized language-dependent performance in the SNWR task was tested first by obtaining Pearson product-moment correlation coefficients among the scores obtained for the Catalan, English and Russian versions of the SNWR task, and then by submitting these scores to one-way repeated-measures ANOVAs. Moderate-to-strong significant positive correlations were found between the Catalan, English and Russian SNWR scores (see Table 1), suggesting that participants generally performed similarly in the three languages. On the basis of previous research (French and O'Brien 2008) we were expecting higher PSTM scores in the Catalan (L1) SNWR task than in the English (L2) and Russian (Lx) SNWR tasks. These predictions were not borne out by the results, as mean percent correct recognition was slightly higher in Catalan and Russian than in English,

and the correlations were stronger between the Catalan and Russian scores. The ANOVA revealed an overall significant effect for Language ($F(2, 82)=3.31$, $p=.041$) and further pairwise comparisons indicated that differences among the scores were only significant between English and Russian ($p=0.35$). Thus, our participants' L1 and Lx PSTM scores did not significantly differ, but their L2 and Lx scores did. This finding does not allow us to make any strong claims as regards the effect of linguistic knowledge on PSTM measures and therefore this issue deserves to be examined in future research. As three different female voices were used in the SNWR tasks, speaker-related differences in intelligibility may have had an effect on the participants' performance.

In order to explore the relationship between PSTM and CSLs' degree of reliance on duration as a cue in the identification of /i:/ (*feet*) and /ɪ/ (*fit*), they were assigned to either Low or High PSTM capacity groups through median split (see Table 1). CSLs correctly identifying 15 (out of 24) nonword sequences or below were assigned to the Low PSTM group in the Catalan and English SNWR task, and 16 or below in the Russian SNWR task. Independent-samples t-tests were then conducted to test whether CSLs with higher PSTM ability performed better in the two-alternative forced choice task. The results revealed significant differences between the Low and High PSTM groups in Russian for the *feet* continuum ($t(82)=-2.37$, $p=.036$). The High PSTM group outperformed the Low PSTM group in Catalan, approaching significance in the English SNWR task ($t(82)=-1.92$, $p=.057$) and reaching significance for the Low and High PSTM groups (Catalan and Russian, averaged) ($t(82)=-2.01$, $p=.047$) and English (see Table 2).

Table 1: PSTM scores and correlations (** $p < .01$)

SNWR percent correct identification				Correlations (Pearson r)	
Nonword language	Mean (SD)	Low PST	High PST	English	Russian
Catalan	63.84 (17.7)	52.87 (10.16) $N=45$	76.49 (6.79) $N=39$.451**	.606**
English	60.91 (14.73)	59.07 (15.52) $N=42$	69.33 (11.64) $N=42$.477**
Russian	65.38 (16.17)	56.56(12.99) $N=37$	73.08 (11.22) $N=47$		

Table 2: % correct identification in the *feet* and *fit* continua as a function of PSTM capacity (Low vs. High).

Catalan			English			Russian		
Cont.	PSTM	Mean (SD)	Cont.	PSTM	Mean (SD)	Cont.	PSTM	Mean (SD)
<i>feet</i>	Low	62.13 (26.15)	<i>feet</i>	Low	58.05 (27.66)	<i>feet</i>	Low	57.79 (25.53)
	High	64.58 (28.37)		High	69.29 (25.37)		High	70.23 (27.69)
<i>fit</i>	Low	59.83 (27.69)	<i>fit</i>	Low	56.00 (26.75)	<i>fit</i>	Low	56.40 (25.46)
	High	62.50 (27.35)		High	66.92 (27.31)		High	66.99 (28.95)

Independent-samples T-tests showed that those subjects in the High PSTM group consistently obtained lower TESs and vice-versa, those in the Low PSTM group obtained higher TESs. These differences approached significance for feet in the High and Low Russian ($t(82)=4.79$ ($p=0.72$)) and Russian and Catalan averaged ($t(82) = 1.87$ ($p=0.71$)) PSTM groups, and for fit in the High and Low Russian PSTM groups ($t(82) = .62$ ($p=.54$)) (see Figures 2 and 3). These results show the duration manipulation had a smaller effect on those participants in the High PSTM group than on those in the Low PSTM, this way resembling more native English speakers in their categorization of /i:/-/ɪ/.

Figure 2: TES of *feet* and SNSW weighted score

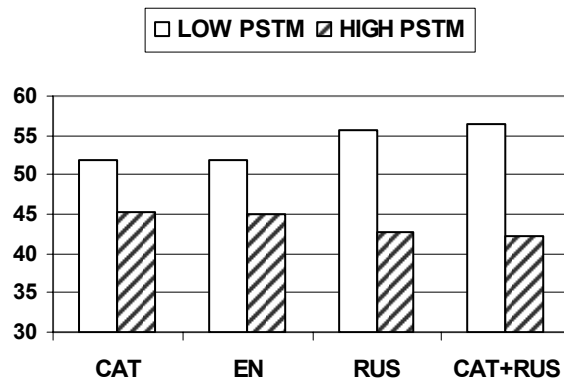
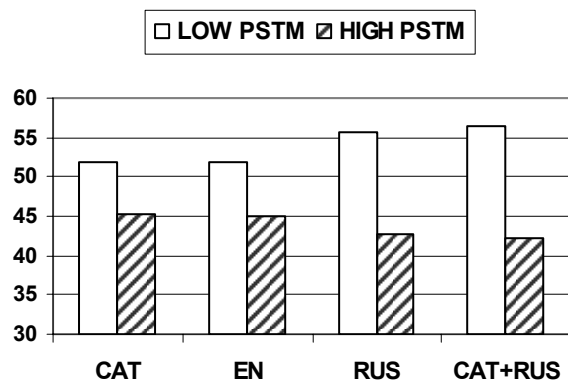


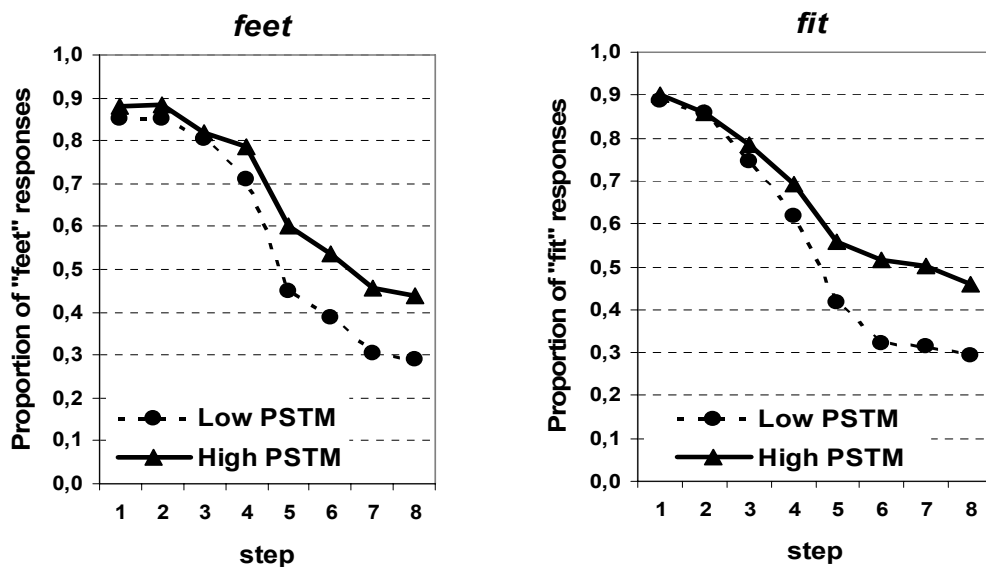
Figure 3: TES of *fit* and SNWR weighted score



An analysis of participants' performance in the two continua as a function of PSTM (High vs. Low PSTM), as defined by participants' performance in both the Catalan and Russian mean SNWR scores, and the extent of duration manipulation (Figure 4), reveals a similar pattern of results along the two continua. High PSTM participants consistently performed better than Low PSTM participants at all 8 steps in the continua. Interestingly, the difference between both PSTM capacity

groups differ along the continua so that the greater the extent of the duration manipulation along the continua, the greater the difference between the High and Low PSTM groups on the proportion of correctly identified stimuli. This suggests that the Low PSTM group is particularly sensitive to duration manipulation when the extent of the manipulation is greater along the continuum.

Figure 4: Results High and Low Catalan and Russian averaged PSTM groups



4. Conclusions

The aim of this study was to investigate the relationship between PSTM and adults' L2 phonological acquisition as a means of gaining a better understanding of the effect of individual differences in cognitive ability on L2 speech learning and cross-linguistic differences in cue-weighting in particular. Firstly a two-alternative forced choice task was designed presenting listeners with two 8-step continua, *feet* and *fit*, in which vowel duration was shortened and lengthened, respectively. The results of this experiment are in accordance with previous research in that CSLs over-relied on duration in the categorization of /i:/ and /ɪ/ and consistent with the explanation provided by Bohn's (1995) Desensitization Hypothesis in that CSLs failed to use spectral differences to distinguish the English /i:/-/ɪ/ and resorted to duration. However, the results of the present study further suggest that differences in PSTM ability may have an effect on the extent to which L2 listeners rely on duration.

Secondly, CSLs were presented with a SNWR task consisting of CVC nonwords conforming to the phonotactic regularities of Catalan (L1), English (L2) and Russian (LX). Statistical analyses showed that the three sets of PSTM scores

obtained were significantly correlated with one another. However, contrary to our expectations, CSLs did not obtain higher PSTM scores in their L1 (Catalan) than in their Lx (Russian) and obtained slightly lower percentage of correct recognition in their L2 (English). This unexpected finding calls for further research. However, the significant correlations obtained for the scores of the three versions of the SNWR task suggest that the three tasks yielded similar measures of PSTM, irrespective of the language of the nonwords. In order to examine the possible relationship between PSTM and native-like cue weighing of /i:/-/ɪ/, CSLs were assigned to either Low or High PSTM capacity groups. The results revealed that those participants in the High PSTM capacity group in each of the three languages obtained higher identification scores in the two-alternative forced choice task than those in the Low PSTM capacity group. CSLs with high PSTM capacity relied on vowel duration manipulation to a smaller extent than CSLs with lower PSTM capacity in the categorization of /i:/-/ɪ/, thus resembling more NSs' use of cue weighting in the categorization of this contrast.

Taken together, the findings of the present study suggest that PSTM may play a significant role in L2 speech learning and they way non-native speakers make use of L2 cue-weighting in the perception of L2 sound contrasts. PSTM, together with other individual differences in cognitive ability, such as attention control or acoustic memory, should be further researched, as such differences might partly explain successful phonological acquisition by adult L2 learners.

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