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PRESENTATION/POSTER

EXPLORING THE PERCEPTION AND PRODUCTION OF L2 FRENCH VOWELS: THE ROLE OF PHONOLOGICAL MEMORY

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This study explored how second language (L2) speech production of French nasal vowels is related to both L2 speech perception and individual cognitive differences in phonological short-term memory (PSTM) and working memory (WM). Thirty-two Australian-English native speakers enrolled in French language courses completed a delayed-repetition task to assess their production and a set of force-choice identification tasks in audiovisual (AV), audio-only (A) and visual-only (V) modalities to measure their perception skills. They then completed a non-word repetition task assessing their PSTM, and a listening span test measuring their WM. Results revealed that accurate production scores were higher for [ɛ̃] (91%), followed by [ɑ̃] (60%), and [ɔ̃] (55%), and that the perception and production scores were strongly correlated (AV: r = .66, A: r = .65, V: r = .68, all with large effect sizes). In terms of individual differences, there was a significant effect of PSTM on production and perception scores, but no effect of working memory capacity. The results are discussed in relation to current research on PSTM and L2 phonology, and with reference to theoretical and pedagogical implications.

INTRODUCTION

Some second language (L2) learners are more successful than others at perceiving and producing L2 contrasts. Variability across individuals can be attributed to a number of factors such as language proficiency, age of L2 learning, and type of instruction, among others. However, variation in the degree of success in L2 learning can also be further explained by differences in general cognitive abilities, including working memory (WM), phonological short-term memory (PSTM), and processing speed. To date, most SLA studies investigating cognitive individual differences have focused on the development of L2 grammar, vocabulary, and fluency (Kormos & Sáfár, 2008; Speciale, Ellis, & Bywater, 2004; Williams & Lovatt, 2003), and little is known about their effects on L2 phonology. Accordingly, the goal of the current study was to further explore the contribution of WM and PSTM on the perception and production of L2 French nasal vowels.

Phonological short-term memory and working memory

One of the most influential conceptualization of WM today is the model developed by Baddeley and Hitch (1974). The model contains three main components each with limited capacities in terms of storage and processing and with relative interdependence: the central executive, acting as the general attentional controller and allocating the finite resources of the WM system, and two slave systems called the phonological loop and the visuospatial sketchpad. The visuospatial sketchpad handles the processing and storage of visual information, whereas the phonological loop deals with verbal and acoustic information and consists of a storage component that holds speech-based information for a few seconds unless the decaying information is refreshed by an articulatory rehearsal process. In a more recent model of WM, Baddeley (2000) added a fourth element—the episodic buffer—which serves as an interface between the short-term storage systems and long-term memory.

While both the executive component of WM and the phonological loop have been implicated in the development of second language acquisition, they are two different concepts and are measured with different tasks. WM, which emphasizes the processing, manipulation, and storage of information, is often assessed with complex tasks such as reading, listening, or speaking span tasks, and has been found to play an essential role in the domains of lexical development (Kroll, Michael, Tokowicz, & Dufour, 2002), grammatical processing (e.g., Coughlin & Tremblay, 2013), and reading skills (Harrington & Sawyer, 1992). High WM is also associated with L2 phonological development (Darcy & Mora, 2015) and enhanced L2 oral performance in complexity, accuracy, and fluency (Mota, 2003), but was not found to be correlated with pronunciation ratings of L2 Spanish (Posedel, Emery, Souza, & Fountain, 2012).

PSTM, on the other hand, is measured with non-word repetition or recognition tasks, digit span tasks, or serial recall tasks, and has been found to be implicated in the development of L2 vocabulary (e.g., Speciale et al., 2004) and grammar and morphosyntax (e.g., O'Brien, Segalowitz, Collentine, & Freed, 2006; Serafini & Sanz, 2016). Phonological memory also accounted for some of the variance associated with oral fluency development (O'Brien, Segalowitz, Freed, & Collentine, 2007) and oral production skills (French, 2006; Kormos & Sáfár, 2008), but very little work has been done specifically on the relationship between PSTM and L2 pronunciation accuracy. Notable exceptions are a study with L1 Japanese speakers (Kondo, 2012) reporting a positive influence of verbal and non-verbal phonological memory on L2 English pronunciation skills, and a study on individual differences in L1 English-L2 Spanish (Nagle, 2013) showing that PSTM correlated ($r = .51$, $p = .002$) with mean pronunciation rating. There seems to be, however, a growing interest in this domain as illustrated by recent conference presentations. For instance, Zahler and Lord (2018) found that high PSTM learners demonstrated acoustic properties that were more closely similar to those of native speakers, with less centralizing of unstressed vowels than low PSTM learners. PSTM abilities did not, however, affect vowel duration, with high and low PSTM learners producing much longer vowels than native speakers. In a similar vein, Kondo (2018) investigated the link between the L2 pronunciation skills of 70 Japanese learners of English and acoustic short-term memory measured with a Tonal Memory Span Test and a Rhythm Memory Span Test. Her results revealed that acoustic short-term memory had significant positive effects on English word reproduction skills, with stronger effects observed for tonal memory capacity.

Connections have also been found between PSTM and L2 speech perception. MacKay, Meador, and Flege (2001) investigated the relationship between PSTM and the perception of L2 English consonants by Italian native speakers and found that phonological memory accounted for 8% to 15% of the variance in identification scores. The advantage of higher PSTM was further demonstrated in a study of English consonant perception by L1 speakers of Greek (Lengeris & Nicolaidis, 2014) and a perceptual training study of L2 English vowels by Catalan/Spanish speakers (Aliaga-García, Mora, & Cerviño-Povedano, 2011). Research on the contribution of PSTM on L2 speech perception is, however, still scant and sometimes contradictory. For instance, PSTM was found to have an important influence on the perception of L2 English /iː/-/ɪ/ cue weighing by Catalan/Spanish bilinguals in Cerviño-Povedano and Mora's (2010) study, but this influence was not replicated in Safronova and Mora's (2012) study.

Research questions

Given the scarcity of research and often conflicting results on the relationship of WM and PSTM to L2 production and perception, this study aims to answer the following research questions:

- How do Australian English learners of French perceive and produce French nasal vowels?
- How is L2 production and perception of French nasal vowels related to individual cognitive differences in PSTM and WM?

METHODS

Participants

The participants were 32 Australian-English learners of French (4 male) between the age of 18 and 33 (mean age = 20.3). They were enrolled in several levels of French at a large Australian university and all had completed at least one full semester of French. None of the participants reported hearing or vision problems.

Production task and production rating

A delayed repetition task was used to collect participants' productions of the three French nasal vowels [ɔ̃-ɑ̃-ɛ̃]. Participants were presented with a total of 108 CVC stimuli where V was one of the nasal vowels followed by a prompt in French inviting them to repeat the word (e.g., "[pɑ̃d] *répète le mot s'il te plait*"). The rating of the participants' productions was conducted with a forced-choice identification task (Inceoglu, 2015) whereby the researcher, also a native speaker of French, listened to participants' recordings and chose which of the nasal vowels had been produced. A second native speaker of French rated 31% of the data (10 participants) with an interrater reliability of 97%. For more details regarding the stimuli, production task, and rating task, see Inceoglu (2016).

Perception tasks

The stimuli for the perception task were the same as those used by Inceoglu (2016). A total of 108 CVC word containing one of the three French nasal vowels [ɔ̃-ɑ̃-ɛ̃] were recorded by a female native speaker of French. The initial consonant was one of the following: [p-t-k-b-d-g-s-z-f-v-ʒ-ʃ] to take into consideration the articulation of vowels in different consonantal contexts. The perception task was administered in three modalities of presentation: audiovisual (AV), audio-only (A), and visual-only (V). The stimuli were the same for the three tasks but were randomized across tasks and participants. Participants heard the stimulus and were asked to identify the nasal vowel by clicking on one of the three options on the screen, <on> on the left, <an> in the middle, and <un> on the right (i.e., [ɔ̃-ɑ̃-ɛ̃], respectively). They had four seconds to make their selection before presentation of the next stimulus, and no feedback was provided. The experiment was conducted using the software program SuperLab (Cedrus, 2015) and was preceded by a practice task to familiarize participants with the procedure.

Phonological short-term memory task

Participants completed a non-word repetition test to assess their PSTM (e.g., Grey, Williams, & Rebuschat, 2015; Kissling, 2014; Lado, 2008). The test consisted of 16 pairs of English non-words, spoken by a female Australian-English speaker, with syllable lengths increasing from 3 (e.g., *melistok, nutolon*) to 8 (e.g., *towarymanitacorous, finterprofensibolities*). Directions were given aurally and in writing, and three additional pairs of non-words served as practice. Participants heard the 16 pairs and were asked to repeat each pair after a two-second delay tone. As the number of syllables increased, the task became more challenging. Participants were awarded one point for each pair that they repeated correctly with no more than one erroneous syllable, resulting in a maximum total of 32 points.

Working-memory task

Participants' WM capacity was evaluated with a sentence span test (Daneman & Carpenter, 1980; Winke, 2013). Participants were aurally presented with 48 unrelated sentences at 3-second intervals in sets of three, four, and five sentences. Half of the sentences were grammatically correct and half were semantically plausible, resulting in four sentence types. For each set, participants were asked to judge the grammaticality and plausibility of the sentences and recall the last word of each sentence before moving on to a new set. Half a point was awarded for a correct judgment of plausibility, half a point for a correct judgment of grammaticality, and one point for each correctly recalled word. This totaled a maximum of 96 possible points.

Procedures

Participants met individually with the researcher in her office. The 1.5 hours data collection session started with participants reading the consent form and filling out a language background questionnaire. They then completed the production task using Audacity and an Audio-Technica AT2020USB microphone (10 minutes), the perception tasks (AV-A-V or A-AV-V; 9 minutes per modality), lipreading tasks that are not discussed in the current study (10 minutes), the PSTM task (5 minutes), and the WM task (20 minutes). For every task involving listening, stimuli were presented via high quality Sennheiser HD380pro headphones. Breaks were provided between each task and at regular intervals within longer tasks to limit the effect of fatigue.

RESULTS

The first goal of the study was to investigate how Australian English native speakers perceive and produce the three Parisian French nasal vowels. Participants' performance on the perception task are illustrated in Figure 1. In the three modalities of presentation (AV-A-V), results showed that [ɔ̃] was the best and [ɑ̃] the least well perceived vowels. A repeated measures ANOVA with modality and vowel as within-subject factors revealed significant main effects of modality (F (2, 62) = 8.569, p = .001, η^2 = .217) and vowel (F (1.62, 50.30) = 17.333, p < .001, η^2 =.359), but no significant vowel × modality interaction (F (3.28, 101.84) = 1.552, p = .202, η^2 = .048). Bonferroni pairwise comparisons indicated no significant differences in vowel perception between the AV and A modalities (p = .404), but significant differences between the A and V modalities (p = .002) and close to significant differences in the AV and V modalities (p = .054). In terms of vowels, participants were significantly better at perceiving [ɔ̃] than [ɑ̃] ($p < .001$) and [ɛ̃] ($p = .005$), but there was no statistical difference between [ɑ̃] and [ɛ̃] ($p = .247$).

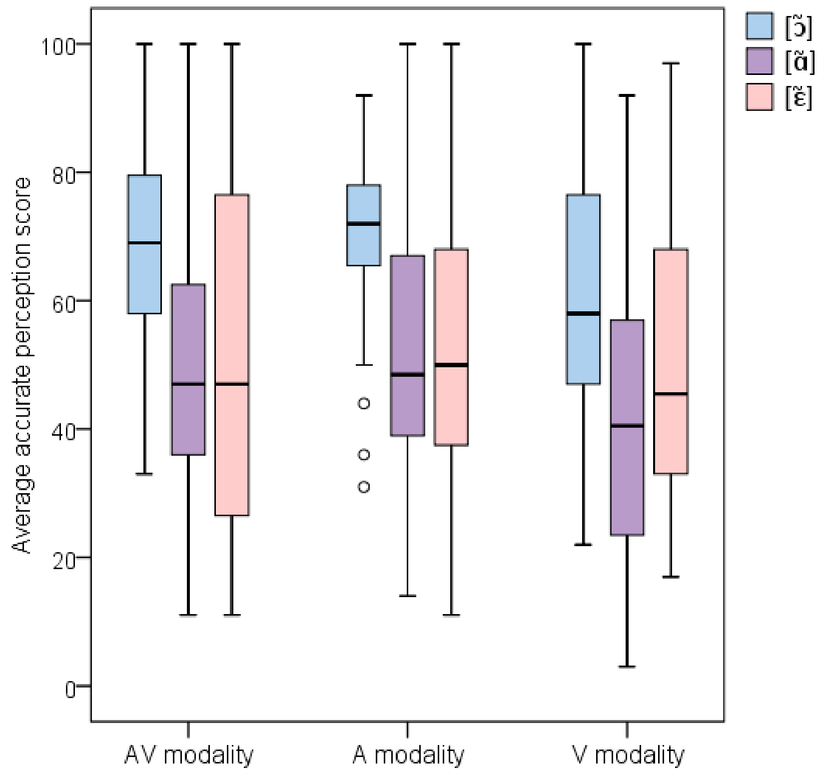

Figure 1. Mean percentage of correct perception scores for each nasal vowel in the three modalities of presentation (AV-A-V).

Results from a repeated measures ANOVA showed that there were significant differences in accurate production of the three vowels (F (1.579, 48.945) = 45.643, $p < .001$, η^2 =.596, *power* = 1.000) with follow-up Bonferroni pairwise comparisons indicating significant differences between [ɛ̃] and both [ɑ̃] and [ɔ̃] ($p < .001$).

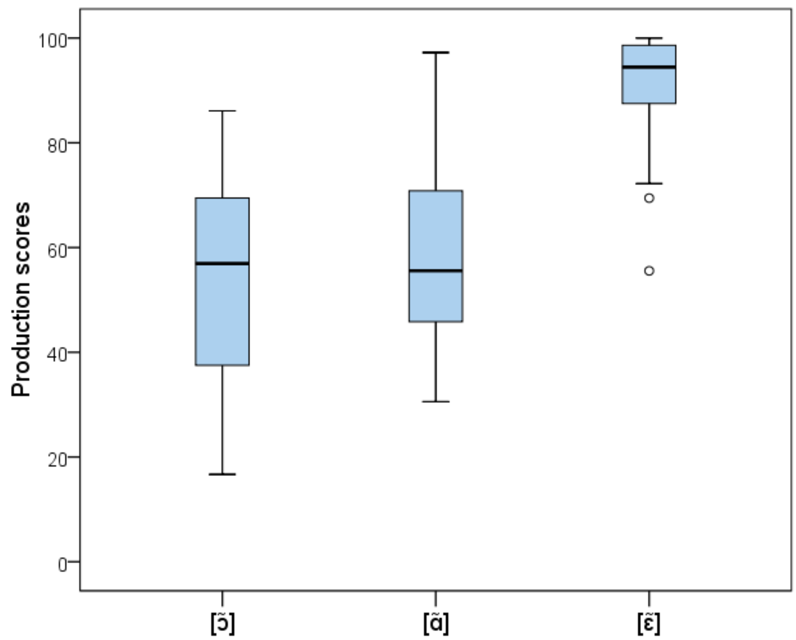

Figure 2. Mean percentage of correct production scores for each nasal vowel.

The second goal of the current study was to explore the relationship between working memory, phonological memory and speech perception. The participants' performance at the verbal WM span test are presented in Table 1, and the mean for the nonword repetition task measuring PSTM was 17.31 (out of 32) with scores ranging from 10 to 24 (standard deviation = 3.97). Results from a bivariate correlation indicated that participants' scores on these two tasks were not related (r = .227, p = .212).

Table 1

Scores for the verbal working memory span test

	Plausibility (max 24)	Grammaticality (max 24)	Recall (max 48)	TOTAL (max 96)
Mean	20.53	19.00	36.28	75.81
SD	1.56	1.83	5.87	6.91
Maximum	23	21.5	48	92
Minimum	15.5	14.5	25	60.5

In addition, participants' production scores were strongly correlated with their perception scores in the three modalities of presentation (AV: r = .66, p < .001; A: r = .65, p < .001; V: r = .68, p < .001). A set of simple linear regression models was performed to examine the extent to which WM and PSTM were predictive of L2 speech perception and production. The results showed a significant, positive relationship of moderate strength between speech perception and PSTM, indicating that learners with higher PSTM scores identified L2 vowels better. This association was significant in all modalities of presentation and indicated that 14% (AV), 21% (A), and 20% (V) of the variance in perception scores could be explained by PSTM. The analysis also confirmed a significant (p = .01) positive relationship between speech production and PSTM, whereby PSTM explained 17% of the variance. However, no relationship between WM and L2 phonology (i.e., speech perception and production) was observed.

DISCUSSION

The first goal of this study was to examine the perception and production of French nasal vowels by Australian English speakers. Results showed that [ɛ̃] was the most accurately produced vowel, with a very high score of 91%, whereas [ɑ̃] (60%) and [ɔ̃] (55%) were less accurately pronounced. These findings are very much in line with a previous study that used the same stimuli and procedures as the current study but was conducted at a US Midwestern university (accuracy scores: [ɛ̃] 78%, [ɔ̃] 61%, and [ɑ̃] 57%) (Inceoglu, 2016). However, in a study with five L1 Japanese and five L1 Spanish high intermediate learners of French, Detey and his colleagues (2010) found that [ɔ̃] was produced more accurately (67%) than [ɑ̃] (54%) and [ɛ̃] (51%). One way of accounting for these differences lies in the two methodologies used to collect learners' production data. On the one hand, the stimuli for the delayed repetition task used in the current study and Inceoglu's (2016) study consisted of 108 CVC tokens in a variety of consonantal contexts. On the other hand, Detey and colleagues (2010) used nine real words in a repetition task and a reading task, raising the issue of lexical familiarity as there is abundant evidence that lexical knowledge influences how L1 and L2 speakers perceive or recognize words (Bundgaard-Nielsen, Best, & Tyler, 2011; Flege, Takagi, & Mann, 1996). Another possible explanation that would need to be further investigated with a larger sample of participants is the L1 background of the learners. In terms of perception, the results of the current study are in line with Inceoglu (2016) showing that [ɔ̃] is significantly more accurately perceived than both [ɑ̃] and [ɛ̃] regardless of the modality of presentation.

The second and main research question explored how WM and PSTM were related to speech perception and production. First of all, the lack of correlation between the two memory tasks provided support for the assumption that PSTM and WM capacity are distinct constructs, as noted by previous studies in other areas of second language acquisition (Gathercole, 2006; Kormos & Sáfár, 2008). Importantly, the current findings revealed that achievement in the L1 PSTM task (i.e., non-word repetition task) was a good predictor for success in L2 speech perception and production. This expanded the important role of PSTM already observed in (L2) vocabulary acquisition (e.g., Speciale et al., 2004), grammar learning (e.g., Ellis & Sinclair, 1996; Williams & Lovatt, 2003) and fluency (Kormos & Sáfár, 2008). Despite differences in target languages and procedures, the current results are in line with previous studies examining speech perception (Cerviño-Povedano & Mora, 2011), pronunciation ratings (Kondo, 2011; Nagle, 2013), and vowel quality production (Zahler & Lord, 2018), and confirmed that PSTM plays a role in the acquisition of L2 speech perception and production. In terms of pedagogical implications, language learners with lower PSTM would benefit from tasks relying on repetition (i.e., activation of the phonological loop) and promoting automatization of the L2 system (Trofimovich & Gatbonton, 2006), which would allow PSTM to be redeployed for the development of long-term memory representations of L2 sounds. Finally, the lack of predictive effect of WM is similar to what Posedel et al. (2012) reported in their investigation of L2 pronunciation development, but differ from Darcy et al.'s (2005) analyses of phonological processing tasks, possibly due to differences in tasks and measures of WM.

To conclude, the current study provided interesting insights into the factors that contribute to successful L2 speech perception and production, and is one of the very few studies that aimed to explore the association between WM, PSTM and speech perception/production. Nevertheless, it is important to stress that research in this domain is still scarce and future work is needed. In particular, future studies should explore the combination effect of proficiency and should expand the investigation to other L1/L2 groups.

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