PHONOLOGICAL ENCODING IN READING ALOUD PERSIAN: ERP EVIDENCE FOR THE PHONOLOGICAL BASIS OF THE MASKED ONSET PRIMING EFFECT

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ABSTRACT

The current study investigates reading aloud (i.e. pronouncing) words in Persian, a language that omits some of its vowels in its script. A word reading task employing a masked priming paradigm did not yield any differences in speech onset latencies between an onset-matching and an onset-mismatching condition. However, event-related potentials (ERPs) did reveal a difference in amplitude between these two conditions, between 190 and 290 ms after target word onset. This finding specifies the masked onset priming effect (MOPE) temporally more precisely and suggests, at least in Persian, the simultaneous activation of both the non-lexical grapheme-to-phoneme and the lexical route in the dual-route cascaded (DRC) model of reading aloud.

Keywords: phonological encoding, GPC, language production, neurophonetics, ERPs

1. INTRODUCTION

The so-called *masked onset prime effect* (MOPE) was first described by Forster and Davis [6] and reflects faster speech onset latencies for reading aloud target words that are preceded by a prime sharing its onset with the target (e.g. *custom* – *CARPET*), compared to an unrelated prime (e.g. *powder* – *CARPET*). This effect has been replicated in English [9, 10, 11, 12], Dutch [16, 17, 18], French [3, 8], and Spanish [5]. Moreover, further research increased our detailed understanding of the MOPE, e.g. that the source of the MOPE is due to phonological (e.g. *kernel* [kɛrnəl] – *CARPET* [kɑrpət]) rather than graphemic onset-overlap (e.g. *circus* [sɪrkəs] – *CARPET* [kɑrpət]; [13, 15, 17]).

According to the Dual Route Cascaded (DRC) model, the MOPE reflects the serial process of converting graphemes into phonemes (GPC) with its locus in the non-lexical route rather than the lexical route [4]. The MOPE has been found for words that are pronounced according to regular pronunciation rules, but not for irregular words [11] – presumably because the correct pronunciation of irregular words requires activation of the lexical route, while it is generally assumed that the MOPE reflects only the non-lexical processes [6].

A more recent version of DRC, called DRC 1.2, assumes that both lexical and non-lexical routes can be simultaneously active [13]. DRC 1.2 suggests that in reading aloud irregular words, a conflict may occur between correct irregular pronunciations activated by the lexical route and incorrect regular pronunciations computed by the non-lexical route, slowing down overall response latencies for reading aloud irregular words. During the time resolving this conflict, the processes that give rise to the MOPE are resolved as well and therefore do not reflect in reaction times. Alternatively, the MOPE may be due to a process later than GPC in the non-lexical route, namely the segment-to-frame association during speech planning [9].

2. EXPERIMENT: READING ALOUD WORDS IN PERSIAN

The goal of the present study is to further investigate the time course of the MOPE in the process of preparing the pronunciation of a written letter string. Employing Persian as the target language in this study may provide information as to which route(s) (lexical and/or non-lexical) is activated during reading aloud. The omission of vowels in the Persian script forms many phonologically opaque words requiring lexical knowledge to be read aloud correctly since many letter strings yield nonwords when incorrect short vowels are inserted [2]. Using an English example, the consonant string *hnch* could be *hanch, hench, hinch, hunch*, but only *hunch* is an existing word, requiring activation of the lexical route in the DRC model. Thus, Persian words can be compared to irregular words in western alphabetical languages, in the sense that both require lexical knowledge.

We also took advantage of the fact that Persian has some inconsistent phoneme-to-grapheme correspondences (so-called polygraphy, i.e. phonemes that correspond to multiple graphemes – e.g. the phoneme /z/ may correspond to four different graphemes, i.e. ذ – ظ – ض – ز [1, 14]). It has been argued that the strength of the MOPE may depend on the consistency of grapheme-phoneme correspondences [7]. We used Persian polygraphy to investigate whether or not native Persians read words aloud faster when preceded by phonologically congruent, onset-matching primes (e.g. /zæri:b/; 'factor' – /zæbɒ:n/; 'language') compared to phonologically incongruent, onset-mismatching primes (e.g. /ʃelæng/; 'hose' – /zæbɒ:n/; 'language').

Besides measuring speech onset latencies (RTs), we recorded the electroencephalogram (EEG). Following Forster and Davis [6], a MOPE may be absent in Persian since it originates in the non-lexical route. However, Persian is (at least partially) read through the lexical route due to the omission of certain vowels in the script. If both lexical and non-lexical routes are simultaneously active, as predicted by DRC 1.2, then a MOPE may be observed in Persian.

Due to a potential slow-down of behavioral responses caused by the above-mentioned competition between lexical and non-lexical pronunciations, the effect may not be observable in RTs. However, electrophysiological recordings (EEG) may provide a remedy. We may observe a difference between the phonologically congruent and incongruent conditions in the EEG signal, even if the MOPE occurs early in processing.

2.1. Method

2.1.1. Participants

Twenty-four native Persian speakers (mean age: 27), half of which were female, took part in the experiment in exchange for a small financial reward. Due to technical failure, one participant was excluded from the analysis.

2.1.2. Materials

Forty-eight target words with the onset phoneme /z/, i.e. twelve target words for each of the four different <z>-graphemes, were selected and combined with a phoneme-match (O–P+; onset matching in phonology but not orthography) and a phoneme-mismatch prime (O–P–; unrelated onset letter). Approximately 90% of the experimental primes and targets were opaque.

In addition, 144 filler words were added, consisting of three sets of 48 words starting with the letters <s>, <sh>, and <m>. Two control primes (both O–P–; unrelated onset) were matched to each filler word. Approximately 90% of the fillers were opaque as well. Familiarity of all experimental and filler stimuli was pretested.

2.1.3. Procedure and design

Participants were seated individually in front of a computer screen in a dimly lit, soundproof room. They were instructed to read aloud target words presented on the screen as fast and as accurately as possible. The visually masked prime words preceding the targets were not mentioned. A voice-key measured the onset of the vocal responses.

The experiment consisted of 384 trials plus warm-up trials, divided into four blocks of 96 trials with breaks in between. Each target word was presented twice (192 target words * two priming conditions). Stimuli were presented in pseudo-random order. In the first two blocks, all target words were presented in one of the two priming conditions, in the last two blocks in the other two conditions. Blocks were counterbalanced across participants.

All stimuli were presented in black letters on a white background and centered on the screen. Each trial started with a fixation point, followed by a forward mask. Then, a prime word was presented for 48 ms, followed by a backward mask. Finally, the target word was presented, followed by a blank screen before the start of the next trial.

2.1.4. EEG recording and analysis

The electroencephalogram (EEG) was recorded using 32 Ag/AgCl electrodes on the standard scalp sites of the extended international 10/20-system. Additional electrodes monitored eye blinks and horizontal eye movements, and a baseline was measured for off-line re-referencing.

The EEG signal was sampled at 512 Hz, and off-line band-pass filtered from 0.01 to 40 Hz.

Epochs from –200 to +500 ms were computed, including a 200 ms pre-stimulus baseline. Eye movement artifacts were corrected. The ERP grand averages were time-locked to the onset of the target word and calculated across all participants for both the phoneme-match and mismatch condition.

3. RESULTS

3.1. Behavioral data

Incorrect responses, as well as voice-key errors and outliers (altogether less than 6% of the data) were removed from the analysis.

A paired-samples t-test was carried out with the factor Phonology (phoneme-match; O–P+ vs. phoneme-mismatch; O–P–) as independent variable and participants and items as random factors. There was *no* main effect of Phonology, i.e. RTs in the phoneme-match condition (708 ms, SD = 80) were not shorter than in the phoneme-mismatch condition (705 ms, SD = 83).

3.2. ERP data

For three time windows (90-190, 190-290, and 290-390 ms), determined by visual inspection of the ERP grand averages, mean amplitudes were submitted to an ANOVA with Phonology (phoneme-match vs. phoneme-mismatch) and Electrode Site (left vs. central vs. right) as independent factors. Averaged ERP waveforms and a topographical distribution of the phonological priming effect can be found in Figures 1 and 2.

3.2.1. Time window 90-190 ms

The analysis revealed *no* main effect of Phonology, but an interaction between Phonology and Electrode Site. The difference in mean amplitude between the phoneme-match and phoneme-mismatch condition was largest in the central brain region compared to the left and right brain regions, but did not reach significance in any region.

3.2.2. Time window 190-290 ms

There was again *no* main effect of Phonology, but an interaction between Phonology and Electrode Site. The phoneme-match condition had significantly larger positive mean amplitudes than the phoneme- mismatch condition in the central brain region ($F(1,22) = 5.56$, $p < .05$). However, in the left and right hemisphere, no effect of Phonology was present.

3.2.3. Time window 290-390 ms

Both the effect of Phonology and the interaction between Phonology and Electrode Site disappeared in this later time window.

Figure 1: Averaged stimulus-locked ERP waveforms for phonological priming with phoneme-match (O-P+; solid lines) vs. phoneme-mismatch (O-P-; dashed lines) for nine electrode sites (left-hemispheric: F3, C3, P3; central: Fz, Cz, Pz; right-hemispheric: F4, C4, P4). (A 20 Hz filter was applied for the clarity of the waveforms.)

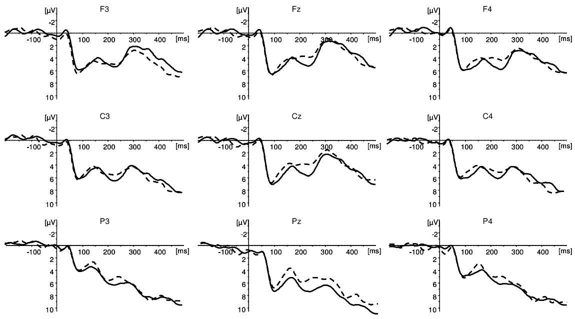
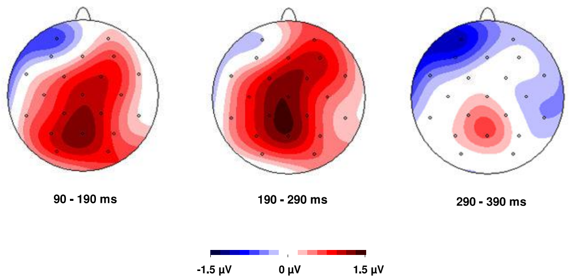


Figure 2: Topographical maps of the difference waves for phonological priming in the three time windows of analysis.



4. DISCUSSION

The current study investigated whether or not a MOPE occurs in Persian and how such a potential effect could be related to current models of reading aloud. We did not find differences in reading latencies between Persian target words preceded by a phonologically matching prime (e.g. /zæriːb/; ‘factor’ – /zæbɒːn/; ‘language’) and a phonologically mismatching prime (e.g. /ʃelæng/; ‘hose’ – /zæbɒːn/; ‘language’). This is in contrast to previous findings for western alphabetic languages, demonstrating that reading aloud target words in Dutch, for instance, was faster when a preceding prime shared the onset phonology with the target (e.g. *kachel* – *CONGRES*) compared to mismatching onset phonology (e.g. *grendel* – *CONGRES*; [17] and see also [3, 8, 13]). In contrast, mean ERP amplitudes for the phoneme-match condition were more positive than for the phoneme-mismatch condition. This phonological onset effect was centrally localized and significant in the 190-290 ms time window.

Persian is different from western alphabetic languages due to the omission of the three short vowels (/æ/, /e/, and /o/) in the script yielding phonologically opaque words. To select the appropriate omitted vowel, all possible options activated through the non-lexical route have to be checked with the lexical entry or entries using the lexical route. Therefore, even skilled Persian readers require the lexical route to read-aloud opaque words correctly [2]. Thus, no MOPE is expected in the RTs for Persian word reading. It is likely that the phonological onset effect revealed by the ERP data occurred during non-lexical conversion processes and reflects a MOPE [6], suggesting that both the non-lexical and the lexical route were active in overt Persian word reading, supporting DRC 1.2 [13].

5. SUMMARY AND CONCLUSIONS

The present results showed that a MOPE for Persian was absent in the RTs but suggested it is present in the ERPs. We propose that both lexical and non-lexical routes are simultaneously activated, as assumed by DRC 1.2. The omission of vowels in Persian generates multiple letter strings within the non-lexical route for a particular opaque word, thereby slowing down processing and eliminating the MOPE (visible in the ERPs) at the endpoint of processing (i.e. reflected in the RTs).

Irregular words in English are also slowed down by conflicting pronunciations from the two routes. If the MOPE has indeed been resolved due to conflict resolution in the time course of word processing, ERPs may also reveal a MOPE for irregular words in other languages, such as English.

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