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Speech Perception of Arabic Pharyngealized Consonants by British and Greek Learners of Arabic

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Abstract

This paper examines the ability of British English and Modern Greek learners of Modern Standard Arabic (MSA) to perceive and categorize Arabic pharyngealized consonants within the perceptual assimilation model (PAM-L2; Best & Tyler, 2007). It explores the categorization patterns of these sounds and compares the performance of British and Greek participants, highlighting how native language phonetic inventories and sociolinguistic factors influence non-native sound perception. Thirty participants, divided into British and Greek groups, underwent two perception experiments assessing their ability to discriminate and categorize these consonants. Results revealed that Greek learners were more successful in categorizing pharyngealized consonants, often assimilating them to non-pharyngealized counterparts, while British learners showed greater difficulty, primarily demonstrating uncategorized patterns. Greek learners categorized [sˤ] and [ðˤ], whereas British learners struggled with all pharyngealized consonants. The findings underscore the influence of learners' native phonetic systems and exposure to Arabic dialects on L2 perception. The study emphasizes the need to consider MSA as a foreign language in curriculum design, given its unique phonetic challenges.

1. INTRODUCTION

Studies have shown that listeners' perception of second language (L2) sounds can be strongly influenced by their first language (Alharbi & Aljutaily, 2020; Best, 1995; Chládková & Jonáš Podlipský, 2011; Evans & Alshangiti, 2018; J. Flege, 1995; J. E. Flege et al., 1997; Iverson et al., 2003), partly because some L1 phonetic inventories do not include certain L2 sounds. For example, Japanese learners of English commonly struggle with /ɹ/ and /l/ (Hattori & Iverson, 2009). Saudi EFL learners also face a similar issue with /p/ (Alharbi, 2013; Al-Rubaat & Alshammari, 2020). Moreover, such difficulties persist regardless of learners' proficiency levels (Evans & Alshangiti, 2018).

In this regard, Best's (1995) Perceptual Assimilation Model (PAM) explains that nonnative contrasts are perceived based on their resemblance to L1 sounds. Best and Tyler (2007) later extended PAM to L2 learners (PAM-L2), positing that learners begin as monolingual perceivers but may develop new phonological categories as they encounter unfamiliar L2 sounds.

Nonetheless, a significant distinction between PAM and PAM-L2 is that PAM-L2 focuses on natural immersion settings, aligning with second language acquisition (SLA) theories: in an L2-speaking country, learners receive ample natural input outside the classroom, whereas learners in foreign language settings are restricted to classroom-based interactions.

Consequently, PAM-L2 underscores how learners' expanding phonological systems reflect both L1 and L2 experiences.

Based on the discussion above, the main purpose of this study is to investigate the speech perception of the four Arabic pharyngealized consonants [ðˤ, tˤ, dˤ, sˤ] by British English and Modern Greek learners of MSA within PAM-L2 as the speech perception model.

Accordingly, this study attempts to provide answers to the following questions:

1. Do British English and Greek learners of MSA categorize Arabic pharyngealized consonants through speech perception?
2. If they do categorize them, to what type of categorization do they assimilate them?
3. Are British English and Modern Greek learners of MSA the same or different in their categorized assimilations?

2. LITERATURE REVIEW

The presence of unfamiliar phonetic contrasts in L2, which might be absent or differ in the learners' native language, poses a substantial hurdle. Learners often struggle with distinguishing sounds that do not exist in their native phonetic inventory, leading to potential inaccuracies in speech perception (Best & Tyler, 2007).

For example, Evans and Alshangiti (2018) examined how Saudi learners of English at varying levels of language proficiency understand and articulate British English vowels and consonants amidst background noise. This study focused on the influence of the learners' first language, namely "Saudi Arabic", on their ability to perceive and produce sounds in their second language, British English. This influence was noted even among those with high language proficiency where the majority of participants faced difficulties perceiving and producing nonnative phonemes such as /ʒ/ as opposite to other native phonemes such as /k/ and /l/. While the findings are consistent with others in the field, it is crucial to highlight that the study failed to recognize the differences between the different Saudi dialects, despite the participants hailing from Riyadh and Jeddah, regions known for their subtly different dialects (Najdi Arabic and Hijazi Arabic, respectively). This oversight means the study's findings lacked specificity; for instance, difficulties with the phoneme /ʒ/, which is prevalent in multiple Hijazi dialects but not in Najdi, were reported collectively (Almohaimeed, 2015; Alrasheedi, 2022; Ingham, 1994). Without distinguishing between the dialects, it was unclear if Hijazi speakers, who naturally use [ʒ] in their dialect, found it easier to perceive than their Najdi counterparts.

Similarly, Al Zahrani (2015) explored how Saudi post-graduate students discern English bilabial stops [p] and [b] in relation to the alveolar stops [t] and [d]. The study presented these phones in various phonetic contexts and positions (beginning, middle, and end of words). The results showed that students accurately perceived phones common to both English and Arabic [t, d, b]. However, they faced more challenges with [p], a phone that, while present in English, only appears as an allophone in Arabic. This difficulty with [p] aligns with findings from similar studies in the field, which often demonstrates a struggle with phones not native to a learner's first language. That being said, the generalizability of Alzahrani's results is limited due to the small sample size (only seven participants) and the absence of rigorous statistical analysis, as the study relied solely on descriptive methods. This contrasts with other studies that often employ larger sample sizes and more comprehensive statistical approaches, offering a broader understanding of language perception among non-native speakers.

In the same vein, Alharbi and Aljutaily (2020) investigated how native Arabic speakers perceive English labial sounds [p, b, f, and v] in onset positions, alongside the impact of phonetic context and stimulus familiarity on their perceptual accuracy. They conducted the study on 24 Saudi male participants, which involved identifying and discriminating tasks between these consonants. Results showed challenges in correctly perceiving [p] and [v], which do not exist in Arabic, often perceiving them as [b] and [f], respectively. Interestingly, the study found that neither the phonetic context, such as surrounding vowels, nor the familiarity of the stimuli significantly impacted the participants' perception, except in cases where [v] was preceded by back vowels, leading to lower performance due to possible lip rounding effects. While the study did not make distinctions among the various regional dialects of Saudi Arabia, this oversight did not impact the results, as the non-existence of both [p] and [v] is a common feature across most, if not all, Arabic dialects.

In an interesting contrast, Salim and Al-Badawi (2017) revealed a different experience with the phone [p] among Jordanian university students learning English. Initially, these students demonstrated a weak understanding of [p], but they showed significant improvement after four weeks of intensive practice. This enhancement in their perception of [p] was attributed not just to the repeated exposure to the sound but also to their overall improvement in English proficiency. This finding contrasts with Evan and Alshangiti's (2018) study, which reported an inverse relationship between language proficiency and sound perception for phones absent in the learner's native language. Although the outcomes of the two studies appear contradictory, the key factor influencing these differences might be the frequency with which the phones, specifically [p] and [ʒ], were encountered by the learners; since [p] appears more frequently in English compared to [ʒ], the linguistic exposure to the former is naturally higher than the latter.

These studies highlight the challenges that unfamiliar phonetic contrasts pose for acquiring non-native sounds. Key insights include the importance of linguistic exposure, as seen in the differential handling of [p] and [ʒ] by learners, and the influence of educational context and language background on phonetic distinction capabilities. While each study presents its unique contributions, the collective research underscores a universal theme: Differences between L1 and L2 phonetic inventories present challenges for L2 learners, specifically in speech perception.

The existing research has already established that Arabic possesses various dialects, each with unique linguistic features. How dialectal and regional differences affect listeners' speech perception is an interesting area of investigation, especially for the topic of this study.

Fox and McGory (2007) explored how adult Japanese speakers perceive and produce regional vowel differences in areas where Southern American English (SoAE) and Standard American English (SAE) are spoken. Their study showed that while native speakers in Alabama and Ohio pronounced vowels true to their regional dialects, Japanese speakers in both areas tended to produce vowels similar to Ohio English, displaying minimal SoAE dialect characteristics. When testing perception, Japanese speakers from both regions struggled more with identifying SoAE vowels, suggesting that living in SoAE regions didn't significantly enhance their understanding of these dialectal vowel variations.

Fox and McGory (2007) suggested that the observed outcomes are influenced by sociolinguistic factors. These factors include the type of English and accent used by EFL teachers, as well as the attitudes of native Japanese speakers and their peers towards nonstandard American English dialects. Additionally, the amount of time these Japanese speakers spend interacting with native speakers of Southern American English (SoAE) plays a role. Together, these elements highlight the complex interplay of sociolinguistic factors in the acquisition of regional dialects by non-native speakers. This emphasizes the significant role of instructional context, social attitudes, and practical exposure in language learning.

While sociolinguistic factors are crucial in dialectal speech perception, they are not the only influential elements. Schmidt's (2018) study investigated how various individual experiences influence L2 learners' ability to perceive dialectal sounds. The research involved 213 English-speaking Spanish learners, each at different levels of proficiency and with varying dialect exposure. They participated in a task to identify the Spanish dialectal aspirated [s^h]. The study found that learners' categorization initially aligned with their first language phonology but gradually shifted towards more native-like, dialect-specific perceptions in experienced learners. Key predictors of this shift included previous study abroad locations, interactions with native speakers, and metalinguistic training, underscoring the impact of individual experiences on developing L2 perceptual skills.

Similarly, Del Saz (2019) conducted a study that focuses on how American Spanish learners perceive the aspiration of the word-final [s] in Western Andalusian Spanish. The study assessed the impact of different listening environments on learners at various stages of language proficiency (beginner, intermediate, proficient). Results indicated that perceptual abilities generally decline in challenging listening conditions, with intermediate learners most affected. Even proficient learners struggled compared to native Spanish speakers, particularly in noisier environments. However, across all listener groups, standard language features were more readily identified, regardless of the listening conditions. The results provided insight into L2 speech perception highlighting how environmental factors and learner proficiency levels influence the perception of dialectal variations in a foreign language.

2.1.PAM-L2 Speech Perception

Al Mahmoud (2013) investigated the feasibility of PAM by examining American learners' ability to discriminate Arabic contrasts. In this study, 22 native American English speakers enrolled in a university-level Arabic language program were assessed on their ability to discriminate between Arabic phonetic contrasts using a forced choice AXB discrimination task. The results offered partial support for PAM. Contrasts fitting into the TC type aligned well with PAM predictions; however, the discrimination of contrasts based on the CG type difference and those deemed uncategorizable provided only partial support. Notably, the discrimination results for UC types contrasts presented evidence contrary to PAM's predictions.

Al Mahmoud's study has two primary issues. Firstly, it focused on American "*learners*", who are not the naïve non-native listeners targeted by PAM. Since these learners had classroom exposure to Arabic, PAM-L2 would be more appropriate for this analysis. Secondly, PAM and PAM-L2 are designed for learners in natural environments where the target language is natively spoken. However, this study examined learners in their native land (an FL environment), not in a setting where Arabic is the first language (an SL environment), which deviates from the model's intended context.

One may argue that Tyler (2019) demonstrated the feasibility of PAM-L2 predictions in an FL environment. Yet, the study emphasized that success depends on early learning experiences that introduce learners to various phonetic differences. Specifically, Tyler stated, "These experiences need to be provided at the earliest possible stages of learning, prior to the establishment of a large L2 vocabulary." (p. 607). Was that the case for Al Mahmoud's participants? Unfortunately, this aspect is neither explained nor discussed in his study. That being said, despite the methodological deviations from PAM, Al Mahmoud's study still offers valuable insights into L2 speech perception, particularly in the context of Arabic phonetic contrasts. It sheds light on how American learners of Arabic perceive and discriminate between various sounds, contributing significantly to the understanding of L2 speech perception dynamics, especially for a less commonly studied language like Arabic.

In a similar context, Millet et al. (2022) compared PAM with advanced fine-grained phonetic representations from machine learning models. Using a novel dataset involving

French and English participants, the study assessed their discrimination of 61 vowel contrasts across six languages. Findings show that PAM, which predicts perception based on the assimilation of unfamiliar sounds into native phoneme categories, outperforms machine learning models, such as wav2vec 2.0 and Dirichlet Process Gaussian Mixture Models, in predicting native language-specific perceptual patterns. While fine-grained models excel in capturing universal phonetic similarities, they fail to replicate language-specific effects that PAM identifies. Importantly, combining PAM with wav2vec 2.0 enhances predictions, highlighting the complementary roles of phoneme-level and fine-grained representations in speech perception.

Tyler's (2020) study focused on the idea that L2 learners might form new language categories but perceive phonological overlap when identifying an L2 sound, meaning they might hear a single L2 phone as belonging to several of their L2 phonological categories. The hypothesis was that with more L2 experience, discrimination accuracy should improve as this overlap decreases. Participants included Japanese native speakers with varying levels of English immersion (i.e., those who studied English in Japan as opposed to those who studied abroad) and native English speakers. They completed a task where they rated the goodness of fit of auditory stimuli to English phonological category labels, namely L, R, W, and Y. Results showed that less experienced Japanese participants rated sounds at the /l/ end of the continuum as good fits for both /l/ and /r/. However, sounds at the /r/ end were better fits for /r/ than /l/. Those with over two years of immersion showed a clearer separation in their ratings at both ends of the continuum, though not as distinct as native English speakers. This pattern suggested that L2 learners perceive phonological overlap between /r/ and /l/, which diminishes with increased immersion experience. Additionally, Tyler indicated that L2 listeners' performance on the task accounted for their responses on /r/–/l/ identification and AXB discrimination tasks, highlighting the potential of assessing category overlap for tracking L2 phonological development. This perceived phonological overlap appears to improve with immersion experience, assessing category overlap a valuable method for understanding L2 phonological progression.

Similarly, Afshar and van Heuven (2022) examined how monolingual Persian and bilingual Azerbaijani-Persian learners of English perceive American English vowels using PAM. The study included 22 monolingual Persian and 27 bilingual Azerbaijani-Persian participants, analyzing how English vowels are mapped onto Persian and Azerbaijani vowel systems. Results revealed distinct assimilation patterns between the groups, with bilinguals benefiting from the three additional central vowels in Azerbaijani, which enhanced their perception of certain English vowels. Despite this, both groups experienced difficulties with tense-lax contrasts, such as /iɪ/ and /uʊ/, though these challenges differed in nature. The findings underscore the influence of native phonological systems on second language acquisition and suggest bilingual vowel systems may offer perceptual advantages.

Bohn and Korneliussen (2023) conducted two experiments investigating how native Kalaallisut (West Greenlandic) speakers perceive English initial consonants as English allows 23 consonants in the onset with voicing contrasts for all obstruents as opposed to Kalaallisut which only allows 12 consonants with no voicing contrasts. Predictions were drawn based on the PAM-L2 model and were attested in the second experiment by way of an identification task similar to previous PAM studies. Contrary to the prediction, aspirated [p^h, k^h] were identified more accurately than [t]. On the other hand, identification accuracy for [ɫ, ɹ, j] was high. Each of these approximants was distinctly assimilated to an L1 category, yet the accuracy for identifying [w] was lower. These two conclusions aligned with predictions as both [w] and [v] received similar ratings for assimilation quality when compared to Kalaallisut. They concluded that predictions of success or failure were due to different reasons, namely the lack of consonants in Kalaallisut in comparison to English, some confusable response labels for some consonants such as for the [θ, ð] contrast, and lastly some participants were familiar with Danish which may have affected the results. Bohn and Korneliussen presented a robust study that offers insights on L2 speech perception focusing on a less commonly studied language like Kalaallisut. However, they acknowledged a potential limitation in their methodology: the inclusion of participants who were familiar with Danish, which might have impacted the accuracy of their predictions.

3. METHODOLOGY

This section provides information about the methodology used for this study, including the participants, stimuli, apparatuses, and procedures for the two experiments. It also presents the data analysis tests and methods.

3.1. Participants

The study targeted native Standard British and Modern Greek beginner-level learners of Arabic. Therefore, the study participants were divided into two main groups. The first group consisted of 15 Standard British beginner-level learners of Arabic, while the second group comprised 15 Modern Greek beginner-level learners of Arabic. The participants in both groups were learning Arabic in either Morocco or Egypt during the experiments.

In addition, all participants had to have normal hearing to rule out any hearing difficulties and developmental issues including age-related hearing problems. Accordingly, the age of the participants was restricted to adults from 20 to 45 years of age. Moreover, they had to be non-Muslims, because Muslims usually receive extensive exposure to Arabic through reading the Quran from a very young age.

To make sure that the above criteria were met, all participants had to undertake a questionnaire prior to the experiments. The questionnaire was written in the participants' respective languages (i.e., English and Modern Greek). It was translated into Modern Greek using a professional Greek translator (gengo.com). All who did not satisfy the criteria were ruled out immediately after the questionnaire.

The questionnaire was designed to collect detailed personal and language information from the participants. It included fields for Full Name, Phone Number, Email, Place of Birth, and Age, with the age requirement set between 20 and 45 years. The participants were also asked if they had been diagnosed with any hearing problems. In the language information section, the respondents provided their First Language and indicated whether they spoke any other languages fluently. The Arabic Experience section explored the participants' history with the Arabic language, asking about the age they began studying Arabic, the frequency of listening instruction in their Arabic classes, and whether they had attended a specialized course in Arabic phonetics. Additionally, the participants reported the number of hours they spoke Arabic daily, with options ranging from 0 to more than 6 hours. Notably, for some participants who objected to sharing their personal data, the fields for Full Name and Phone Number were excluded.

Moreover, the study utilized three different ways of recruitment:

1) The participants were approached by the researcher through emails sent to several Arabic teaching institutions in Egypt and Morocco, such as Al Diwan Center, Ibaanah Center, and Nile Center in Cairo, Egypt, and Moroccan Center for Arabic Studies and Lankey in Rabat Morocco.
2) Other participants were recruited by the researcher through posts on two subreddit on Reddit (r/learnarabic and r/SampleSize).

3) Online recruitment websites were also used to extend the search for suitable participants. Primarily, some participants were recruited through Surveycircle.com, a free service that uses a points system to allow researchers to recruit participants based on specific criteria. Additionally, Positly.com was used to meet the recruitment size target. This paid service acts as a medium between participants and researchers by applying specific screening conditions, such as first language and current residence.

At the end of the experiments, 30 participants successfully completed it. According to Table 1, the participants were equally divided into 15 males and 15 females. Among the British participants, there were 9 males and 6 females, while the Greek participants comprised 6 males and 9 females. The average age for both groups was 30.97 years, with British participants averaging 28.6 years and Greek participants 33.3 years. The mean age at which the participants began learning Arabic was 23.4 years for the British and 32.3 years for the Greek, averaging 27.9 years across all participants.

Table 1: *Participants' Information*

Group	Male	Female	Mean Age	Mean Age Starting Arabic
British Participants	9	6	28.6	23.4
Greek Participants	6	9	33.3	32.3
Total	15	15	30.9	27.9

Two linguist male native speakers of Arabic (one of which is the researcher) recorded the targeted MSA contrasts, viz. [ðˤ, ð], [tˤ, t], [dˤ, d], and [sˤ, s] as shown in Table 8. The recordings were tested for authenticity by a graduate native speaker of MSA since, as established earlier, not all of the pharyngealized consonants exist in all Modern Arabic dialects. The speech recordings were digitally recorded at a sampling rate of 44.1 kHz in an /Ca/ environment using Praat (Boersma & Weenink, 2024) and were eventually saved in separate files to control the pauses between tasks during the experiments. The arrangement for the stimuli (3 consecutive consonants with 1 sec in between) was done using the online mixing service clideo.com.

Furthermore, the recordings were blended with speech-shaped noise (SSN) at a Sound-Noise Ratio (SNR) of 5 dB using Praat to prevent a ceiling effect, a common approach in many PAM studies such as those by Chládková & Jonáš Podlipský (2011). Additionally, A script originally developed by Quené & van Delft (2010) and later updated by Listen Lab (2023) was employed in Praat to generate the SSN and integrate the noise with the original recordings.

Table 2: *Target Contrasts*

Contrast	Type
[ðˤ, ð]	multiple articulations (emphatic vs non-emphatic)
[tˤ, t]	multiple articulations (emphatic vs non-emphatic)
[dˤ, d]	multiple articulations (emphatic vs non-emphatic)
[sˤ, s]	multiple articulations (emphatic vs non-emphatic)

4. DATA ANALYSIS

The data was collected first using the exported Excel files from Gorilla.sc. Next, the data was cleaned using Microsoft Excel 365, while RStudio was employed to perform the statistical analyses for this study as well as to create various plots and charts.

The data for both tasks was analyzed individually per participant and collectively by group using descriptive analysis. Additionally, a two-way ANOVA was conducted to evaluate if there was a statistical difference in performance between the two groups.

4.1.Procedure

For the data collection, a discrimination task was conducted for the first task and an identification task was done for the second. The following provides an overview of the tasks and how they were conducted.

All participants completed a forced-choice AXB discrimination task in which they were asked to listen to trials arranged in a triad AXB. The task was designed using the *Gorilla* online service. In this task, the participants listened to all possible AB combinations of both speakers' recordings (i.e., AAB, ABB, BAA, and BBA, 16 trials per male speaker, 32 trials in total), which were presented randomly. For example, for the [s, sˤ] contrast, the participants listened to the following AXB tasks (sssˤ, ssˤsˤ, sˤss, and sˤsˤs). Additionally, they listened to eight distracting trials (25%) and did 3 familiarization tasks that followed the same process explained above, prior to the actual task. Accordingly, each participant took part in 43 trials in total, during which, following the different PAM studies (e.g., Al Mahmoud, 2013), the interstimulus interval was 1s and the intertrial interval was 3s.

Prior to the task discrimination task, the participants signed a consent form presented to them in their respective languages. Then, they completed a questionnaire which was used as a second screening process after the first one presented by the recruitment service discussed earlier.

During the discrimination task, the participants were presented with two buttons (A and B). After they listened to each AXB sequence, they were asked to press A if the first two tokens were the same and B if the last two were the same. If they did not know the answer, they were encouraged to guess. To reduce anxiety, the participants were told to replay the recordings as many times as they wanted; their responses, however, cannot be changed once given. After each trial, the participants were asked to rate the similarity between their choice and X on a scale of 1 (distinct) to 7 (identical). All instructions were presented to the participants in their native languages before the beginning of the task.

As for the identification task, it began with a written instruction presented to the participants in their native languages. The participants were presented with a grid containing keywords, shown in Table 4, written in their native language and representing the sounds that contrast with pharyngealized consonants in Arabic [ð, t, d, s]. The orthographic representation of the contrasts is written in bold and underlined. In addition, the grid contains four distracting keywords. After listening to each token, the participants were asked to choose the most similar consonant from the grid by clicking on it. They subsequently rated their choice based on the similarity between the token and the chosen keyword on a scale of 1 (very strange) to 7 (perfect).

Table 4: *Keywords Used in the Grid for Task 2*

Phone	BE	Transcription*	MG	Transcription	Translation
[ð]	**th**is	[ðɪs]	**δ**ύο	[ðʝ`o]	two
[s]	**s**it	[sɪt]	**σ**όφια	[s`o·fça]	Sofia the capital of Bulgaria
[t]	**t**en	[tɛn]	**τ**αχύς	[tixis]	rapid
[d]	**d**en	[dɛn]	**ν**τροπή	[drop`i]	shame
Distractors					
[z]	**z**oo	[zu]	ζήλια	[zija]	Jealousy
[b]	**b**it	[bɪt]	**μ**προστά	[brost`a]	in front
[k]	**k**it	[kɪt]	**κ**όσμος	[k`ozmos]	world
[g]	**g**et	[gɛt]	**γ**κρεμός	[grem`os]	Cliff

Note: For the English words, the transcriptions were done by the researcher, and for Modern Greek, it was retrieved from bab.la online dictionary.

5. RESULTS AND DISCUSSION

This section presents both descriptive and statistical results, accompanied by the necessary tests and charts. The analysis begins with individual-level results and gradually scales up to demonstrate the overall groups' results.

Task 1

Starting with the first group (British Participants), herein referred to as Group BR, Tables 5 and 6 provide detailed representations of the percentages of correct responses for the discrimination task for each participant.

Table 5: *Percentages of Correct Contrast Discrimination (Group BR)*

Participant*	[dˤ, d]	[sˤ, s]	[tˤ, t]	[ðˤ, ð]
10857222	100	100	100	100
10878890	37.5	37.5	37.5	50
10878893	87.5	100	100	100
10878896	25	50	50	62.5
10878906	62.5	50	37.5	12.5
10879198	50	25	50	37.5
10879214	100	100	87.5	75
10879267	100	100	87.5	100
10879364	62.5	37.5	25.0	50
10879644	75	62.5	37.5	12.5
10879693	37.5	12.5	12.5	62.5
10879909	100	37.5	62.5	100
10879912	50	37.5	37.5	87.5
10879921	12.5	37.5	50	50
10879929	25	100	50	37.5

Note: Participants' IDs were allocated automatically by gorilla.sc after each completed attempt.

Examining individual scores reveals substantial variability in the ability of participants to discriminate between the contrasts. Notably, several participants, such as Participant 10857222 and Participant 10879267, demonstrated exceptional discriminative proficiency by consistently scoring 100% across multiple contrasts. This level of performance indicates a robust perceptual acuity for these phonetic distinctions.

In contrast, other participants displayed considerable fluctuation in their scores, underscoring diverse challenges in contrast to discrimination. For instance, Participant 10878906 achieved a high of 62.5% in the [dˤ, d] contrast but only 12.5% in the [ðˤ, ð] contrast, suggesting differential discrimination abilities to these sounds.

Overall, as shown in Table 5, while some participants consistently showed high discriminability across contrasts, others struggled with specific distinctions.

Table 6 highlights the individual performances on contrast discrimination for the Greek participants (Group GR). The data reflects a wide range of scores across the four phonetic contrasts: [dˤ, d], [sˤ, s], [tˤ, t], and [ðˤ, ð].

Table 6: *Percentages of Correct Contrast Discrimination (Group GR)*

Participant*	[dˤ, d]	[sˤ, s]	[tˤ, t]	[ðˤ, ð]
10878895	100	87.5	100	87.5
10879031	50	62.5	50	50
10879805	100	100	100	100
10879858	50	62.5	37.5	37.5
10880214	100	100	100	100
10880245	100	87.5	100	87.5
10880247	62.5	50	50	50
10880255	50	37.5	62.5	87.5
10882506	100	100	87.5	100
10882744	75	50	50	12.5
10884328	100	87.5	87.5	100
10892982	87.5	87.5	100	75
10893001	100	100	100	100
10893039	100	87.5	100	87.5
10895271	100	100	100	100

Note: Participants' IDs were allocated automatically by gorilla.sc after each completed attempt.

Several participants demonstrated exceptional proficiency in contrast discrimination, with Participants 10879805, 10880214, 10893001, and 10895271 achieving perfect scores of 100% across all contrasts. This indicates a highly developed ability to distinguish between these pairs, suggesting a robust perceptual perception within this group.

Conversely, some participants exhibited significant variability in their performance, which may highlight individual differences in their discrimination ability. For instance, Participant 10880255 scored 50% in [dˤ, d], 37.5% in [sˤ, s], 62.5% in [tˤ, t], and 87.5% in [ðˤ, ð]. This variability suggests that certain contrasts may be more challenging for some participants than others, potentially due to the individual linguistic backgrounds or experience.

Overall, the performance in Group GR suggests that while many participants excel at contrast discrimination, others face challenges with specific ones. This analysis does not only highlights the diverse capabilities within the group but also sets the stage for further investigation into the factors that influence their discrimination proficiency.

Table 7: *Descriptive Statistics for Contrasts Discrimination (Group BR Analysis)*

Contrast	Mean*	Percentage*	Standard Deviation
[ðˤ, ð]	5.00	62.50%	30.61%
[tˤ, t]	4.40	55.00%	27.06%
[dˤ, d]	4.93	61.67%	30.80%
[sˤ, s]	4.73	59.17%	31.86%

Note: The mean and percentage here refer to the correct discrimination attempts by all participants in Group BR.

When comparing the contrast discrimination abilities of Groups BR and GR, the analysis revealed distinct patterns in performance and variability. Both groups demonstrated high levels of proficiency across the different categories, yet Group GR consistently outperformed Group BR in both sum scores and percentage accuracies (see Table 7 and Table 8).

Table 8: *Descriptive Statistics for Contrasts Discrimination (Group GR Analysis)*

Contrast	Mean*	Percentage*	Standard Deviation
[ðˤ, ð]	6.2	78.33%	27.73%
[tˤ, t]	6.5	81.66%	24.10%
[dˤ, d]	6.8	85.00%	21.24%
[sˤ, s]	6.4	80.00%	21.54%
Note: **The mean and percentage here refer to the correct discrimination attempts by all participants in Group BR.**			

Group GR's superior performance is evidenced by higher sum scores and percentage accuracies across all categories. For example, the mean sum score for the [d - dˤ] category in Group GR was 6.8, compared to 4.93 in Group BR, with percentage accuracies of 85% and 61.7%, respectively. In the case of the [t, tˤ] contrast, Group BR achieved a mean sum score of 4.40 with an accuracy rate of 55%, while Group GR outperformed them with a mean score of 6.5 and an accuracy rate of 81.66%. Similar trends are observed in other categories, highlighting Group GR's robust discriminatory capabilities.

However, an analysis of variability, as indicated by standard deviations, shows a more specific picture. Group GR exhibited higher variability in scores, especially noted in the [ð - ðˤ] category, where the standard deviation reached 27.73%, compared to 30.61% in Group BR. This suggested that while Group GR generally performed better, its participant responses were more varied, potentially reflecting broader individual differences in contrasts discrimination or MSA linguistic exposure.

Previous studies on PAM and PAM-L2 have demonstrated that participants can distinguish between contrasting parts if they achieve scores above a specific threshold on discrimination tasks. Consistent with literature such as Tyler et al. (2014), this dissertation sets the threshold at 50%. Accordingly, all participants in both study groups successfully distinguished between all contrast sets, as evidenced by their average scores exceeding 50%.

To test the differences between Group BR and Group GR, a two-way ANOVA test was conducted. Table 9 shows the final result of the two-way ANOVA test.

Table 9 :*Two-way ANOVA test for Both Groups BR and GR*

Term	df	Sum SQ	Mean SQ	Statistic	P-Value
Groups	1	90.1	90.1	19.1	0.0000277
Contrasts	3	2.60	0.867	0.184	0.907
Both	3	3.00	1.00	0.212	0.888
Residuals	112	528	4.72	NA	NA

Table 9 presents the results of a two-way ANOVA conducted to evaluate the influence of both groups (BR and GR) and the contrast category. The analysis shows that the group factor is highly significant, with a p-value of 0.0000277, indicating strong differences between Group BR and Group GR.

In contrast, the contrast factor, and the interaction between group and contrast, do not show significant effects, with p-values of 0.907 and 0.888, respectively. This suggests that while the groups differ significantly in their overall measures, the specific types of contrasts do not significantly differentiate within or between these groups.

The results highlight the importance of group differences in this analysis while suggesting that contrast types and their interactions with groups do not contribute significantly to variance in the dependent variable.

Task 2

Table 10 :*Task 2 Results for Group BR*

		Labelled Consonants (Response)							
		b	**d**	**g**	**k**	**s**	**t**	**ð**	**z**
Stimulus	[d]	8.33%	65.00%	0	0	0	11.67%	5.00%	10.00%
	[dˤ]	15.00%	11.67%	5.00%	16.67%	6.67%	21.67%	6.67%	16.67%
	[ð]	11.67%	10.00%	0	0	1.67%	8.33%	68.33%	0
	[ðˤ]	20.00%	8.33%	10.00%	13.33%	6.67%	20.00%	11.67%	10.00%
	[s]	8.33%	1.67%	0	0	70.00%	3.33%	3.33%	13.33%
	[sˤ]	11.67%	3.33%	8.33%	6.67%	38.33%	5.00%	8.33%	18.33%
	[t]	13.33%	5.00%	5.00%	10.00%	5.00%	53.33%	8.33%	0
	[tˤ]	23.33%	5.00%	8.33%	8.33%	6.67%	28.33%	5.00%	15.00%
Mean		13.96	13.75	4.58	6.88	16.88	18.96	14.58	10.42
SD		4.71	18.51	3.66	5.69	21.74	14.46	19.29	6.22

Table 10 details the response distribution for stimuli as categorized into consonant labels by participants in Group BR during Task 2. Each row indicates a specific stimulus ([d], [ð], [dˤ], [ðˤ], [s], [sˤ], [t], [tˤ]), with corresponding participant categorizations across eight consonant labels (b, d, g, k, s, t, ð, z) listed in the columns. Percentages in the table show how often each stimulus was identified with a particular label, alongside mean percentages and standard deviations for each label.

The data reveal that the stimulus [s] achieved the highest recognition accuracy, with 70% of responses correctly identifying it as [s]. This is closely followed by [ð], correctly identified by 68.33% of participants. Both [s] and [ð] were also misidentified. Notably, [s] was misidentified as z in 13.33% of cases and as b in 8.33% of cases. Similarly, [ð] was misidentified as [b] in 11.67% of cases and as [d] in 10.00% of cases. In contrast, [d] was less accurately identified, with a majority of 65% but notable misidentifications as b (8.33%) and z (10.00%). As for the [t] stimulus, it showed moderate accuracy, with 53.33% of responses correctly labelling it as [t], but notable misidentifications included [b] (13.33%) and [k] (10%).

The responses for pharyngealized sounds [dˤ, ðˤ, sˤ, tˤ] displayed considerable variability. For example, [dˤ] was identified as [t] only 21.67 % of the time and was also identified as equally as [k] and [z] (16.67%) and [d] (11.67%). Similarly, [ðˤ] saw 20% of participants labelling it as [b] and 13.33% as [k]. The stimulus [sˤ] was identified as [s] only 38.33%, as [z] (18.33%), and [b] (11.67%).

Table 11: *Task 2 Results for Group GR*

		Labeled Consonants (Response)							
		/b/	**/d/**	**/g/**	**/k/**	**/s/**	**/t/**	**/ð/**	**/z/**
Stimulus	/d/	3.33%	61.67%	18.33%	0	5.00%	3.33%	6.67%	1.67%
	/dˤ/	31.67%	18.33%	8.33%	0	3.33%	26.67%	11.67%	0
	/ð/	16.67%	18.33%	0	1.67%	0	1.67%	56.67%	5.00%
	/ðˤ/	55.00%	6.67%	5.00%	1.67%	3.33%	1.67%	25.00%	1.67%
	/s/	3.33%	0	0	5.00%	78.33%	1.67%	3.33%	8.33%
	/sˤ/	3.33%	1.67%	1.67%	3.33%	83.33%	1.67%	3.33%	1.67%
	/t/	1.67%	3.33%	5.00%	20.00%	3.33%	63.33%	0	3.33%
	/tˤ/	46.67%	5.00%	3.33%	10.00%	3.33%	23.33%	5.00%	3.33%
Mean		20.21%	14.38%	5.21%	5.21%	22.50%	15.42%	13.96%	3.13%
SD		20.16%	19.06%	5.62%	6.37%	33.73%	20.58%	17.70%	2.42%

With respect to Group GR, Table 11 shows varied participant response distributions to the stimuli in Task 2. The stimulus [sˤ] received the highest categorization, with 83.33% of participants identifying it as [s]. This is closely followed by [s], identified as [s] by 78.33% of the GR participants. In contrast, the stimulus [d] was identified by 61.67% of the participants, with a notable misidentification rate of 18.33% as [g].

Among the pharyngealized sounds, [ðˤ], [dˤ], and [tˤ] exhibited significant misidentification patterns. The sound [ðˤ] was particularly challenging, with 55.00% of responses incorrectly labelling it as [b], while only 25.00% of participants accurately identified it as [ð]. Similarly, [dˤ] demonstrated considerable variability in identification, with 31.67% of responses categorizing it as [b] and 26.67% as [t]. The stimulus [tˤ] also faced notable misclassification, being identified as [b] in 46.67% of responses and as [t] in only 23.33% of cases.

6. INTERPRETING THE FINDINGS

With respect to the first question "*Do British English and Greek learners of MSA categorize Arabic pharyngealized consonants through speech perception?*", both British English and Greek learners of MSA demonstrated the ability to discriminate between Arabic pharyngealized consonants. This ability was evident in their performance on the discrimination tasks, where the average scores for both groups exceeded the 50% threshold. However, there were notable differences in the level of proficiency between the two groups. In terms of categorization, the Greek learners successfully categorized two pharyngealized consonants, [sˤ] and [ðˤ]. However, the British learners were unable to categorize pharyngealized consonants, failing to meet the 50% threshold. Therefore, the answer to question 1 is two-fold: The British learners were unable to categorize any of the four Arabic pharyngealized consonants whereas the Greek learners were able to categorize two of them viz. [sˤ] and [ðˤ] but failed to categorize [tˤ] and [dˤ].

For the second question "*If they do categorize them, to what type of categorization do they assimilate them?*", on the one hand, the British learners were unable to categorize Arabic pharyngealized consonants, with all four contrast pairs falling into the UG type according to PAM. This means one sound was assimilated to a native category, while the other did not assimilate to any category and was rendered uncategorized. For example, for the [s, sˤ] contrast, the first was assimilated to the L1 native category of [s], while the second failed to reach the 50% threshold for any given native category. On the other hand, the Greek learners categorized [sˤ] and [ðˤ], frequently assimilating them to their non-pharyngealized counterparts. However, they also failed to reach the 50% threshold for two sets of contrasts, namely [t, tˤ] and [d, dˤ]. Therefore, the categorization types for Greek learners are UG for [t, tˤ] and [d, dˤ], and CG for [s, sˤ] and [ð, ðˤ].

As for the final question "*Are British English and Modern Greek learners of MSA the same or different in their categorized assimilations?*", the two groups differed in their categorized assimilations. The Greek learners were generally more successful in categorizing pharyngealized consonants, while the British learners failed to categorize any of the pharyngealized consonants. Moreover, as mentioned in the answer to the second research question, the British learners only have one type of PAM categorization (i.e., UG) for all sets of contrasts, whereas the Greek learners have two types (i.e., CG and UG). Additionally, a two-way ANOVA test revealed a significant statistical difference between both groups, regardless of the contrast type, indicating that contrast type plays no role in the differences, as they exist between the two groups under all contrasts.

6.1. Contextualizing the Findings

Previous research has consistently shown that learners face significant challenges when distinguishing sounds that do not exist in their native phonemic inventory (Best & Tyler, 2007).

For instance, Evans & Alshangiti (2018) highlighted difficulties the Saudi learners faced with non-native phonemes such as /ʒ/. Similarly, Al Zahrani (2015) and Alharbi & Aljutaily (2020) documented the struggles Saudi learners had with the English voiceless bilabial stop /p/, since it is not present in Arabic.

These studies highlight the significance of phonetic inventory differences in L2 speech perception, consistent with the findings of this study where both British and Greek learners encountered difficulties with Arabic pharyngealized consonants which are absent in English and Modern Greek. This is demonstrated by the results drawn from Tasks 1 and 2. For instance, although Group BR collectively distinguished the contrasts in Task 1 by scoring above the 50% threshold, the standard deviation across the four contrast groups ranged from nearly 27% to 32%, indicating considerable individual differences among the British participants. Specifically, 33.33% (n = 5) of Group BR struggled to differentiate between the two parts of each contrast pair. In Task 2 for Group GR, the identification percentages for the consonant [dˤ] varied significantly across the eight labels, ranging from 0.00% to nearly 32%. Similarly, identifications for [tˤ] varied from approximately 0.00% to almost 47%. These illustrate the challenges L2 learners encounter when trying to perceive sounds that are not part of their native phonetic inventories.

The findings also revealed a statistically significant difference between Group BR and Group GR. Additionally, individual performance variability within both groups was evident, as shown by the differing results. This raises a new point of discussion: what causes these differences? Both groups underwent the same individual screening process and were controlled accordingly. Neither group has the target consonants of this study, namely Arabic pharyngealized consonants, in their native phonetic inventories.

An important factor that could have influenced the differences between the learners pertains to L2 dialectal variation. Fox & McGory (2007), Schmidt (2018), and Del Saz (2019) emphasized the role of dialectal variations in L2 speech perception. These studies highlighted how learners' exposure to different dialects and regional accents influenced their ability to perceive and produce non-native sounds. That Greek learners outperformed British learners in categorizing Arabic pharyngealized consonants could be partially explained by differences in dialectal exposure and sociolinguistic factors influencing their perceptual strategies. As previously established, the diglossic status of Arabic-speaking communities creates a complex situation for Arabic learners, where exposure to MSA outside the classroom is limited. This includes exposure to Arabic pharyngealized consonants. For instance, an L2 Arabic learner in any of the Gulf States (Saudi Arabia, Kuwait, Qatar, etc.) would not be exposed to the consonant [dˤ], as it is replaced by [ðˤ] in the regional dialect spoken in everyday situations. Consequently, the necessary exposure for perceptual learning, as suggested by PAM and PAM-L2, is either missing or insufficient, being limited to the classroom environment.

7. CONCLUSION

The primary objective of this study was to examine whether British English and Modern Greek learners could perceive and categorize Arabic pharyngealized consonants. Additionally, the study aimed to determine the nature type of categorization and to compare the responses between these two groups.

The findings revealed significant insights into the perceptual abilities of British English and Modern Greek learners regarding MSA pharyngealized consonants. Greek learners demonstrated a higher proficiency in categorizing these consonants compared to British learners. Greek learners exhibited categorized and uncategorized patterns, often assimilating pharyngealized consonants to their non-pharyngealized counterparts. In contrast, British learners primarily demonstrated uncategorized patterns, reflecting challenges in assimilating these sounds to their native phonological categories.

7.1.Implications

The findings of this study have several important implications for both theoretical understanding and practical applications in the field of L2 speech perception.

First, the study highlights the impact of native language phonetic inventory on the perception of non-native sounds. Learners from two different native language backgrounds exhibited varying levels of difficulty in perceiving Arabic pharyngealized consonants, which were not present in their native phonetic inventories. This finding underscores the importance of considering the specific phonetic properties of learners' L1 when designing L2 teaching methodologies and materials.

Second, the observed differences between British and Greek learners in categorizing Arabic consonants suggest that factors beyond phonetic inventory, such as dialectal exposure and sociolinguistic context, play a critical role in L2 speech perception. This implies that L2 instructional strategies should be tailored to address these contextual factors, potentially incorporating more varied and authentic exposure to target language sounds in diverse dialectal contexts to enhance perceptual learning.

Finally, based on the results of this study, teaching MSA—whether as a second or foreign language—should be approached as teaching a foreign language, at least for perceptual learning. The absence of certain elements of MSA in the natural environment -such as the differences discussed concerning MSA pharyngealized consonants- hinders natural exposure to these perceptual elements. Therefore, more perceptual training and natural elements need to be incorporated into the classroom. In addition, more perceptual exercises should be implemented inside the classroom when teaching MSA especially for sounds that are absent in the dialect spoken outside the classroom.

7.2.Limitations of the Study

This study provides valuable insights into the research area, but it is important to recognize certain limitations that might have affected the generalizability of its findings. While the experiments offered substantial answers to the research questions, the sample size and demographic focus were constrained, examining only British English and Modern Greek learners of MSA. Although appropriate for the research questions, these groups and the sample size of 30 participants—typical for speech perception studies—were insufficient to generalize the findings to all MSA learners. Methodological considerations also influenced the results, including the use of noise (SNR 5dB) to limit the ceiling effect, which might have impacted beginner-level participants' performance. The use of online experiments instead of on-site sessions, while simplifying recruitment, lacked control over listening conditions and limited the researcher's ability to provide assistance. Recruitment challenges further complicated the study due to strict eligibility criteria, including the exclusion of Muslims, specific age ranges, beginner proficiency, and no prior phonetics training. These factors, while not significantly affecting the findings, highlight the challenges in ensuring broader applicability and control in the study.

7.3.Future Recommendations

The study suggests that future research should continue to explore the complex interactions between phonological, phonetic, and sociolinguistic factors in L2 speech perception. Longitudinal studies examining how these factors influence perceptual learning over time could provide deeper insights into the processes underlying successful L2 phoneme acquisition. Additionally, expanding research to include a broader range of non-native phones and learner populations would further enhance the generalizability of these findings and support the development of comprehensive models for L2 speech perception.

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