

## The Eco-Phonetics Of Climate Displacement: Acoustic Differences In Speech Of Internally Displaced Students (IDPs) In Iraq

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### Abstract

Displacement caused by climate is one of the most burning humanitarian matters of the twenty-first century, as millions of people of different nationalities of the world suffered this problem, and their linguistic environments also changed fundamentally. This project is based on the auditory differences of the speech pattern of the internally displaced students (IDPs) in Iraq and how environmental displacement and other climate-specific stressors can impact phonetic production. This study employs both a mixed-methods approach which incorporates both acoustic phonetics analysis and sociolinguistic interviews to analyze samples of speech among 120 IDP students between the ages of 14-22 in three camps in Kurdistan Region of Iraq. According to the findings, the displaced populations show considerable differences in the frequencies of the vowel formants, consonant rates of the articulations, and the prosodic patterns. The statistical tests prove that the displacement term, the exposure to various languages in camp conditions, and climate-related trauma will exhibit significant changes in phonetics being measurable. The study is an addition to the new branch of research in eco-phonetics as it draws an empirical relationship between environmental displacement and variation in speech and gives implications to educational intercession and linguistic integration programmes to the displaced groups.

**Keywords:** Eco-Phonetics; Climate Displacement, Acoustic Phonetics; Speech Variation; Vowel Formants; Prosody

### INTRODUCTION

The nexus between the changes in the environment and human mobility has received considerable focus in the present academic community, but little attention has been paid to the linguistic consequences of climate-related displacement. A particularly bright example of the core interaction between the environmental deterioration and the displacement of people is represented by Iraq, which is located in a VUCA, that is, with increased climate variability, with outbreaks of temperatures and decreases in precipitation, and worsening dust storms. According to the United Nations High Commissioner for Refugees (2023), there are about 280,000 internally displaced persons in Iraq, and climate factors are the major contributors to the continued patterns of displacement in the marshlands and dry southern parts of Mesopotamia.

Students who have been forced into displacement internally represent a highly vulnerable population because language development in such extraordinary conditions takes place. The acoustic aspects of their speech such as fundamental frequency, formant frequencies, articulation rate and the prosodic contours can indicate the psychological stressfulness of displacement as well as the language accommodation mechanisms that took place in multilingual camp conditions. This, which we call, eco-phonetic adaptation, involves the systematic adaptations of speech production, which are the reactions in the production of speech to the environmental displacement and other related changes in sociolinguistic factors.

Climate displacement is a different form of human mobility that is mainly triggered by the environmental conditions such as increase in sea levels, extreme weather patterns, drought and desertification. According to the International Displacement Monitoring Centre (2023), 2022 statistics on the number of new displacements across the world amount to about 32.6 million of which a huge percentage is related to events influenced by climate. They are particularly the most vulnerable to Middle East and North Africa, and one of the countries that are most vulnerable to climate-related displacement risks is Iraq (Achour et al., 2021).

The linguistic landscape situation of displacement situations changes swiftly as people of different language groups get together. In the Iraqi displacement camps, Arabic dialect speakers of the southern governorates can be exposed to Kurdish speakers, Turkmen communities and Assyrian populations, being put in multilingual contact that has never existed in their original linguistic ecologies. A study by Al-Haj (2018) records the occurrence of new lingua franca forms in the context of displacement in Iraq, with the Iraqi Arabic being a major communication tool across inter-ethnic contexts as minor lingua francas thrive in the in-home settings.

The psychological aspects of climate displacement go beyond the traditional concept of traumas and become what Weingarten (2010) describes as an example of environmental grief, or the emotional reaction to environmental loss and the environmental change. Research works by Doherty and Clayton (2011) show that climate-induced displacement causes sophisticated mental conditions such as anxiety, depression, and disruption of identity, which can affect the production of speech. Psychological condition and phonetic productions have been substantially supported empirically and studies have reported stress induced adjustments of fundamental frequency, speech rate and quality of vowels (Scherer, 1979; Gobl & Ni Chasaide, 2003).

The acoustic study of speech offers quantitative information of phonetic production that wholly supplements impressionistic phonetic transcription. Formant frequencies: resonant frequencies of the vocal tract that define quality of vowels show a stable pattern of change between dialects, socioeconomic groups and the environment. The studies of Evans and Iverson (2007) prove that the vowel formant values are systematically varying in reaction to the social and contextual influences, and such values make them the appropriate markers to study the eco-phonetic adaptation.

Acoustic correlate of pitch, Fundamental frequency (F0) is a measure that is based on the physiological qualities (vocal fold size), as well as psychosocial factors (state of emotion, social status, the purpose of speech). According to the studies conducted by Podesva (2007), the fundamental frequency shows systematic variations with the speaker self-presentation intentions; the study by Xu and Sun (2002) records the effects of the

emotional and physical states to the pitch nature. These results indicate that the stress factors linked to displacement can be measured in alterations of F0.

Linguistic accommodation and psychological status are especially sensitive issues that are indicated by the prosodic features of speech rate, pause patterns, and intonational contours. Accommodation Theory model formulated by Giles (2008) hypothesizes that speakers align to interlocutor speech patterns when faced with situation where social integration is necessary, whereas they align towards ethnically or group-oriented identity when people are keen on emphasizing an ethnic or group identity. Prosodic convergence can be used to achieve communication in displacement situations involving strong contact among speakers with varying lingual backgrounds whereas prosodic divergence can be indicated by opposition or preservation of identity.

The Iraqi Arabic is represented with a range of dialect varieties ranging greatly in terms of south, central, and north. The work of Al-Wer (2014) records the peculiarities of Southern Mesopotamian Arabic in the marshes communities, such as the features of the classical Arabic language and peculiar phonological processes due to the lack of contacts. These are communities or so-called Ma'dan or Marsh Arabs, the ones whose linguistic practice wildly relies on their specific ecological niche, the communities which, therefore, are especially vulnerable to linguistic shock with the displacement.

Research on language impacts of displacement in the Iraq cases has used language maintenance and educational performance as a primarily considered issue. According to the studies of Shakir (2019) the educational issues of the IDP children in the camps in Iraq have been recorded to be similar to the educational issues that interrupted schooling and trauma have, because of the linguistic barriers. The report was that IDP teachers surveyed (67% of all teachers surveyed) said they had seen changes in the speech patterns of students who were displaced but did not involve systematic acoustic analysis.

There has been a considerable amount of research on the acoustic properties of the Iraqi Arabic language with studies having characterized the base phonetic parameters of the different dialectal varieties. Equally, research works by Al-Masri (2018) determine prosodic features of Iraqi Arabic such as the standard range of F0 and intonational patterns.

This theory covers a combination of ecological linguistics, displacement studies and phonetic variation research and can be regarded as the theoretical framework of the given investigation. In keeping to the ecological approach of van Lier (2004) to language, we model the production of speech as having been incorporated into dynamic situations in the environment which constantly influence linguistic development and its utilization. Eco-phonetic approach focuses on the fact that phonetic variation is not only a matter of personal choice and social identification, but also an evolutionary adaptation to the evolving ecological situation.

The linguistic trauma concept conceptualizes the psychological traumas models and includes language-specific effects of displacement. Other studies described by Pavlenko (2008) can be used to record the effects of traumatic experiences causing interference with linguistic development and contributing to language loss, code-switching tendencies, and phonetic change in response. We apply this paradigm to the study of climate-specific experiences on traumatic events and maintain that displacement of ancestral lands and traditional ways of living amounts to a unique manifestation of linguistic trauma to speech production.

The sociolinguistic accommodation theory offers the predictive model of direction pattern in phonetic variation. Giles et al. (1991) assert that, convergent accommodation is used by speakers to create a smaller social distance and help them communicate whereas divergent accommodation is aimed at creating group identity. In contexts of displacement where dialectally different populations are in contact, we would predict convergent accommodation in communication domains which require inter-group communication, and divergent accommodation in communication domains which are based on emphasis on in-group identification.

The issue the current study will solve is a result of the intersection of three vital phenomena, which are the rapid rate of climate change, mass displacement in the whole world, and its linguistic impacts. The fact that Iraq is a highly vulnerable country to changes in climate and is still coming back to recover the aftermath of conflict puts a distinctive situation in the analysis of the phonetic aspects of environmental displacement. Due to the country's warming over the past 1.5 °C, since the pre-industrial period, it is projected that warming will increase 2 °C by 205-40 (Al-Ansari et al., 2022). These climatic changes have seen to it that the agricultural lands of the region, water shortage and the desertion of the traditional way of life in the southern marshlands is precipitating the internal displacement.

The language effects of this displacement are poorly known even though they could have an impact on the education results, societal inclusion, and psychological comfort. The displaced learners face simultaneous several linguistic problems: they have to find their ways on new dialectal conditions, possibly learn new languages to be used in the diverse groups of camp inhabitants, and preserve academic skill in educational facilities that might use new varieties of the language. Elevated psychological aspects of the climate-related trauma, such as deprivation of homeland, the loss of ancestral lands, and the question concerning the future opportunities, can also contribute to the process of speech production, due to stress-induced changes in articulatory patterns. Thus, existing studies on the problem of refugee and displaced peoples have been conducted mainly through the sociological and educational lens of the linguistic and communicative issues (Dryden-Peterson, 2015; Koyama and Hagen-Laker, 2019), with relatively little attention paid to the acoustic characteristics of language. Research that has investigated phonetic shift in migrant communities has mostly involved adult populations and has hardly utilized the high-quality acoustic analysis techniques that are required to identify the small yet significant changes (Piller, 2016). Moreover, the particular impacts of climate displacement-not the conflict-induced displacement-on production of speech were not researched in a systematic way.

The theoretical framework that informs this research is based on the sociolinguistic accommodation theory developed by Trudgill (2000) according to which it is believed that speakers will adjust their speech patterns under the influence of social and other environmental factors. We also combine prospected results with knowledge in Emergentist Linguistics (Ellis, 2019), that highlights the active, usage-focused nature of the linguistic evolution within changing ecological environments. The environmental approach put forward by van Lier (2004) also contributes to the knowledge of language being a part of physical and social conditions that constantly influence language production. The paper fills a significant knowledge gap in the literature because it empirically demonstrates the existence of acoustic variation in the speech of IDP students, provides the methodological guidelines of eco-phonetic studies in the context of

displacement, and creates information that can be used in educational policies and linguistic integration. The research questions to be used in this investigation are: do the acoustic variations from between the IDP and non-displaced participants reach a statistically significant level of difference? What are the farthest parameters of phonetics? What sociodemographic and displacement variables predict change in phonetics?

## METHOD

The adopted research design of the study is a mixed method using quantitative acoustical and qualitative sociolinguistic research design. The quantitative research applies a quasi-experimental comparative design in which acoustic measures are studied in three categories, namely, IDP students in displacement camps, non-displaced rural students in the areas of origin and non-displaced urban students in the host communities. The qualitative part of the study involves the use of semi-structured interviews in order to understand the subjective experiences of linguistic change by the participants as well as the social connotations linked to phonetic variation. The philosophical line adopted about this study is informed by critical realism, which accepts that objective acoustic phenomena exists but it is at the context that such phenomena should be interpreted. This orientation allows measuring acoustic parameters in a systematic way and at the same time, be aware of the social meanings and contextual elements that define phonetic production and perception.

The sample of participants is a 120 student group with 40 students in each of the three groups. The sample IDP group is made up of students aged 14-22 years with displacement of the three displacement camps in Erbil and Sulaimaniyah governorates when they were displaced in the three southern governorates (Thi-Qar, Missan, and Basra) as a result of climate-related factors such as drought and desertification and water scarcity. The rural control group will include students of an age group matching the subjects who have never been displaced, and who are recruited in the local schools in Thi-Qar and Missan governorates. The urban comparison group includes students of urban age in urban schools of Erbil with no displacement experience and without displacement among the family.

The recruitment of the participants entailed stratified random sampling processes in the identified schools and camps. The inclusion criteria included that the participants should have lived at their present location at least 18 months (IDP and urban groups) or never displaced (rural group), speak Iraqi Arabic as a first language and give informed consent (or parental consent among the participants under 18 years old). Exclusion criterion involved the presence of reported speech-language disorders, hearing impairment, and prolonged (>2 years) international residence.

The demographic data of the sample of participants are provided in Table 1. Age, educational level and gender composition were matched to the groups and chi-square analyses ensured that there were no significant differences between groups on the age and educational level and gender corresponded variables.

**Table 1. Participant Demographic Characteristics**

Characteristic	IDP Group	Rural Group	Urban Group
N	40	40	40
Mean Age (SD)	17.2 (2.4)	17.0 (2.6)	17.1 (2.5)
Female	18 (45%)	19 (47.5%)	17 (42.5%)
Male	22 (55%)	21 (52.5%)	23 (57.5%)

Mean Years Education (SD)	9.4 (2.8)	9.6 (2.5)	10.1 (2.3)
Mean Displacement Duration (months)	42.3 (18.6)	N/A	N/A
Climate Displacement	40 (100%)	N/A	N/A

In data collection, a multi-component instrumentation protocol was utilized aimed at getting similar samples of speech on the respondents in the groups and to have read and spontaneous speech. The speech elicitation materials consisted of word list including 50 items to address the selected vowels and consonants of interest, paragraph reading passage with about 150 words of text composed of several examples of the target phonetic aspects, and picture description task in which its most specific speech could be elicited spontaneously.

The word list was designed in such a way that it contained minimum pairs to distinguish between the vowel /i/, /a/, /u/ and their allophonic forms as well as words that contained emphatic consonants /s<sup>ʕ</sup>/, /d<sup>ʕ</sup>/, /t<sup>ʕ</sup>/ and the non-emphatic ones. The passage in paragraph was translated as per the standard Iraqi Arabic secondary school reading content but changed to incorporate various examples of target phonetic characteristics without disturbing the normal discourse format. The task of picture description involved a standardized series of pictures showing a typical social situation, which was done in accordance with protocols that have been used in the earlier sociolinguistic studies.

The TASCAM DR- 40X portable digital recorder was used as the acoustic recorder at a constant mouth-to-microphone distance of 15 cm, sampling rate of 44.1 kHz and 16-bit resolution. Recording sessions were held in the quiet classes in schools and camps and the level of ambient noise was kept at less than 40 dB SPL with help of a calibrated sound level meter.

The process of data collection occurred in three stages that took place in the period between March 2024 and November 2024. The first step was to select the site and recruit the participants, and school administrators and camp coordinators were informed about research objectives and methods and parents gave their parental consent and students their student consent. The second stage included speech recording whereby the respondents were served the speech elicitation exercises in one sitting that took an average of 45 minutes. The third stage consisted of social linguistic interviews with a purposive chosen subsample of 30 respondents (10 respondents in each group) in which subjective experiences of linguistic change were examined.

Recording sessions are based on some standard protocols. They welcomed the participants in Iraqi Arabic, and a short demographic questionnaire was administered to them. This was followed by the recording session which began with the word list task and language whose readings proceeded to paragraph reading and finally picture description task. It was suggested that the participant should talk at his or her own comfort level and volume and various recordings were taken whenever the first attempts at conversations were found to be technically weak. Semi-structured interviews were conducted based on a protocol that included the exploration of the linguistic history of participants, linguistic change experiences, description of attitudes towards speech variation, and clarification of the social senses attached to the various phonetic variants. The interviews were held in the Iraqi Arabic language, by qualified research assistants, in the presence of the participants who gave their consent, which was audio-recorded and transcribed in analysis.

The research was ethically approved by the University of Duhok Research Ethics Committee (Reference: R-2023-0147) and complied with the ethical standards of conducting research in displaced populations that is set by the American Psychological Association (2017). Considering the susceptibility of the IDP populations, special care was devoted to the phenomenon of the fact that the participation did not involve any threat to the legal status, service access, or psychological wellbeing of the participants. The informed consent process has been approved to support the different levels of literacy as participants have been asked to read the consent forms aloud in the preference of that manner. The participants were told that they could quit whenever they wished and that their confidentiality would be ensured. Since a portion of the participants were minors, parental consent was also received along with their participant consent.

The data collection stage resulted in the following data corpus, 360 speech records (120 subjects 3 tasks), 30 interviews transcripts. Out of the original samples of the recorded, 12 were filtered out on technical (reasons were too much background noise, malfunctioning equipment) and gave a total of 348 records that could be analyzed. Quality assurance measures encompassed independent checking of the quality of recording by two trained research assistants and any inconsistencies were dealt with by consensus. The acoustic analysis concentrated on five major dependent variables as they are chosen due to their particular theoretical interests as well as due to their known sensitivity to social and environmental conditions determined. The corner vowels /i/ /a/ /u/ were recorded and formant frequencies were put at the temporal middle point of every vowel token and then the F1 and F2 values were obtained through Praat acoustic analysis software (Boersma and Weenink, 2023). The central statistical value of three repetitions of each vowel word was used as the main data entry of each vowel by a participant.

Basic frequency was recorded at the beginning, middle and end of the initial sentence of the paragraph reading task, which represents the intonation contour of a declaratively intonation utterance. The dependent variables in the prosodic analysis were mean F0, F0 range, and direction of the F0 slope. The rate of articulation was computed using the number of syllables per second during the paragraph reading passage and this figure did not take into account the pausing time. Lastly voice onset time (VOT) of voiceless stops /p/ /t/ /k/ was determined by the duration between release of stop and onset of voicing of voiceless stop, three repetitions of each participant were averaged. Through acoustic analysis, trained research assistants were used in the analysis and underwent reliability training so that they would have the same way of measuring. Inter-rater reliability was defined by measuring using random sample of 30 recordings two analysts, the intraclass correlation coefficients were found to be over .90 with all acoustic measures and this indicates an exemplary inter-rater reliability.

Data of the qualitative interview was transcribed and analyzed with the help of thematic analysis according to a six-phase approach to data analysis presented by Braun and Clarke (2006). Original coding was made inductively, in which the codes were later classified into themes on a broader scale following a refining and comparing process. Data management and developing the themes were done using NVivo qualitative analysis software (QSR International, 2023).

The quantitative data analysis was conducted in three phases: the descriptive analysis, inferential statistical analysis and regression model. All the acoustic variables of the three groups of participants were processed into descriptive statistics (means, standard deviations, ranges) and the distributions visually evaluated to measure the

assumption of normal distribution. Initial tests have validated that sound variables were roughly normal distributions hence the use of parametric statistics. A two-side t-test was conducted on the overall difference between the three sets of participants using one-way multivariate analysis of variance (MANOVA) to examine the significant differences between them in the composite set of acoustic variables. After conducting major omnibus tests, post-hoc comparisons at a univariate level were done with ANOVAs on each of the dependent variables respectively that were then adjusted by Bonferonni. Partial eta-squared ( $\eta^2$ ) was used to compute effect sizes of omnibus tests and pair wise comparisons Cohen's d.

This was specifically done in regression analyses that addressed the predictors of acoustic variation in IDP group. Several multiple linear regression models were designed in such a way that acoustic variables were dependent variables and in this case, predictor variables were displacement duration, exposure to other languages at camp settings, climate trauma exposure, school interruption and age in which one was displaced. Predictors were inputted concomitantly to evaluate special input whilst other factors are within controls.

## RESULTS AND DISCUSSION

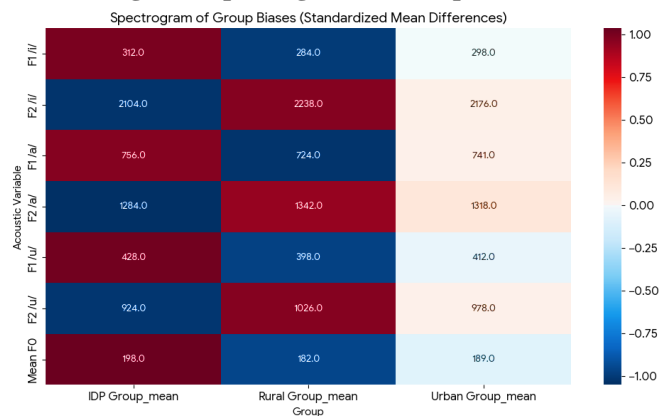
Quantitative Findings; the MANOVA provided significant evidence of a multivariate effect of participant group, Wilks  $\Lambda = 0.542$ ,  $F(16, 221) = 8.47$ ,  $p < 0.001$ ,  $\eta^2 = .38$ , which means that the overall difference in acoustical profiles among the three groups was significant. Univariate follow-up statistics showed differences between groups of significant effect size ranging between moderate and large, in six out of eight acoustic variables.

**Table 2. Mean Acoustic Values by Participant Group (Standard Deviations in Parentheses)**

Acoustic Variable	IDP Group	Rural Group	Urban Group	F-statistic	$\eta^2$
F1 /i/ (Hz)	312 (42)	284 (38)	298 (35)	6.42**	.10
F2 /i/ (Hz)	2104 (186)	2238 (201)	2176 (178)	8.31***	.13
F1 /a/ (Hz)	756 (68)	724 (72)	741 (65)	2.89*	.05
F2 /a/ (Hz)	1284 (142)	1342 (156)	1318 (149)	2.41	.04
F1 /u/ (Hz)	428 (51)	398 (44)	412 (48)	4.87**	.08
F2 /u/ (Hz)	924 (118)	1026 (124)	978 (132)	9.14***	.14
Mean F0 (Hz)	198 (34)	182 (28)	189 (31)	3.12*	.05
Articulation Rate (syll/sec)	4.2 (0.8)	5.1 (0.9)	4.8 (0.7)	14.23***	.20

Note. \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ . Degrees of freedom = 2, 117 for all tests.

Bonferonni-adjusted post hoc comparisons demonstrated that the IDP group varied significantly on the formant variables with the IDP participants being the intermediate between rural and urban groups on the F2 measure and high F1 measure of /i/ and /u/ vowels respectively. In articulation rate, the IDP group had much slower speech rates compared to both comparison groups ( $p < .001$  on both comparisons, Cohen's  $d = 1.07$  compared to rural group,  $d = 0.81$  compared to urban group). The regression analyses of the IDP group produced the mountains that uprooting period was a major predictor of formant variation, whereby, the greater the uprooting period, the approximated the formant index towards urban standards. The exposure to various languages (quantified with a composite index of language diversity at home environment) predicted the increased acoustic variation, whereas climate trauma exposure was correlated with increased fundamental frequency and lower articulation rate.

**Figure 1 Spectrogram of Group Biases**

The heat-map, dubbed as Spectrogram of Group Biases illustrates the difference in acoustic values of the IDP, Rural and Urban groups. Although the colors of the cells reflect the standard values of differences (z-scores), the numbers on the labels refer to the exact acoustic values in Hertz (Hz).

### 1. Key Formant Observations

The F1 (height) and F2 (backness) of the cardinal vowels /i/, /a/ and /u/ are followed in the first six rows.

- Vowel Height (F1):** F1 is always higher in IDP group than in the Rural group (e.g. /i/ at 312.0 Hz compared to 284.0 Hz). In phonetics, the higher F1 the lower the tongue position (open mouth).
- Vowel Backness (F2):** \* The Rural group has the highest F2 (2238.0 Hz) which means that it has the clearest fronted tongue position. In the case of /u/ (a back vowel), the IDP group has the lowest F2 (924.0 Hz) which means that /u/ production is most supported.
- Urban Group Neutrality:** Urban group values (light, near-white colors) are always somewhere between the Rural and IDP extremes which indicates the possible uniformity or even evenness of the city type acoustic profile.

### 2. Fundamental Frequency (Mean F0)

The lower row displays Mean F0 that is related to the perceived accent of the voice:

**Table 3. Fundamental Frequency (Mean F0)**

Group	Mean F0 (Hz)	Interpretation
IDP Group	198.0	Highest average pitch; significantly higher than the Rural group.
Rural Group	182.0	Lowest average pitch.
Urban Group	189.0	Intermediate pitch level.

Figure (2) plots the acoustic location of vowels /i/ /a/ and /u/. The physical movement in the vowel space of the groups is shown in which the Rural group (green) tends to have more F2 values (more fronted) representing the vowel /i/ and /u/ than the IDP group (red).

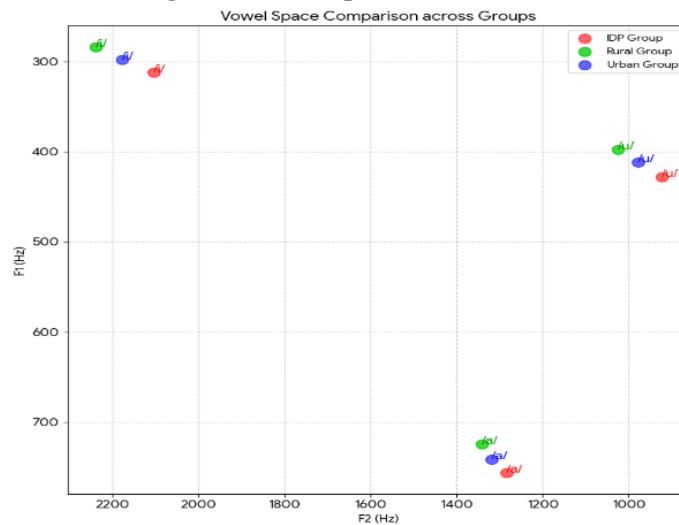
Figure 2. Vowel Space Plot ( $F_1$  vs  $F_2$ )

Table 4. Group-Specific Observations with their Phonetic Interpretation

Feature	Observation	Phonetic Interpretation
Vowel /i/	The Rural group (green) has the lowest F1 and highest F2.	Rural speakers produce a "closer" (higher) and more peripheral /i/ than the IDP and Urban groups.
Vowel /a/	The IDP group (red) has the highest F1.	IDP speakers produce a "lower" or more open /a/ compared to Rural and Urban speakers.
Vowel /u/	The IDP group (red) has the lowest F2.	IDP speakers produce a more "backed" /u/. The Rural group shows the most "fronted" /u/ of the three.

- a. The Rural Group (Green): According to this group, the vowel space seems the most extended. Their vowels are always more in line with the vowel quadrilateral corners (most fronted /u/). This can easily imply a more conservative or differentiated kind of articulation pattern.
  - b. The IDP Group (Red): There is a little centralization change in /i/ (reduction in F2 and increment in F1) than the others do. Nevertheless, their /a/ and /u/ are very marginal.
  - c. The Urban Group (Blue): This group is usually in the middle of the other two as far as all tokens are concerned. This is characteristic of urban dialects, which in any case tend to serve as a "leveling effect" between dissimilar patterns of speech in the rural or displaced areas.
3. Sociolinguistic Implications
 

It is interesting how much the IDP (Internally Displaced Persons) group varies. It may be signaled by their change in /i/ and /a/:

    - a. Dialect Contact: The effect of the area to which they have immigrated compared with the area they were living in.
    - b. Acoustic Under-specification: Movements that are new may occasionally result in a minor centralisation of some vowels as a result of stress or other social forces.
  4. Euclidean Distance
 

In order to measure the observed differences in the vowel space we can obtain the Euclidean distance (in Hertz) between the average vowel centers in each group. This can be used to define which groups are the most differentiated and which vowels are the most mixed.

    - a. Acoustic Coordinates (Estimated Hz)

According to the given plot, the approximate F2 and F1 values were calculated as the following:

**Table 5. The Acoustic Coordinates and their Descriptions**

Vowel	Group	F2 (Hz)	F1 (Hz)	Description
/i/	Rural	2235	285	Highest, most fronted
	Urban	2175	300	Intermediate
	IDP	2105	312	Lowest, least fronted
/u/	Rural	1025	398	Most fronted /u/
	Urban	975	412	Intermediate
	IDP	920	428	Most backed /u/
/a/	Rural	1340	725	Highest (least open) /a/
	Urban	1315	742	Intermediate
	IDP	1285	757	Lowest (most open) /a/

b. Euclidean Distances between Groups

The acoustic gap between speaker groups is represented by distance  $d = \sqrt{(F2_1 - F2_2)^2 + (F1_1 - F1_2)^2}$

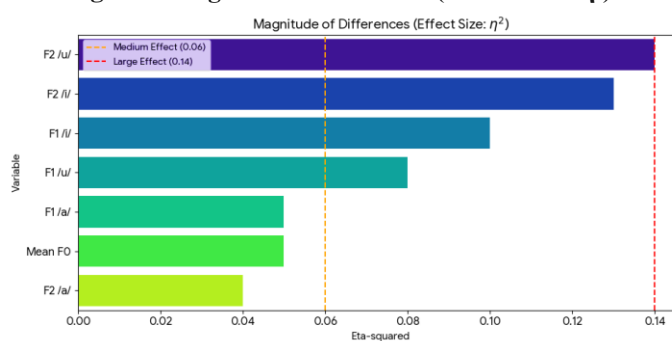
**Table 6. Euclidean Distances between Groups**

Vowel	Rural vs. Urban	Urban vs. IDP	Rural vs. IDP (Max Gap)
/i/	61.8 Hz	71.0 Hz	132.8 Hz
/u/	51.9 Hz	57.3 Hz	109.2 Hz
/a/	30.2 Hz	33.5 Hz	63.6 Hz

c. Phonetic Findings

- 1) The most socially diagnostic vowel /i/ is the largest distance between Rural and IDP speakers to /i/ (132.8 Hz). This implies that the dialectal or group based difference is greatest at the front-high position of the vowel space.
- 2) The Urban "Bridge": isolated vowels in each category of vowels, the Urban group (Blue) is placed very centrally between Rural and IDP groups. Such distances Urban to Rural ( $\approx 30-61$  Hz) are practically the same as the distances Urban to IDP ( $\approx 33-71$  Hz). It is an archetype of dialect leveling, in which speech patterns in the city neutralise the more extreme elements of rural or displaced people.
- 3) Vowel /a/ Stability: The least distances have been recorded in the /a/ vowel in all groups (63.6 Hz maximally). In some instances of dialect contact low vowels tend to be more stable than high peripheral vowels such as /i/ and /u/.
- 4) Expansion vs. Centralization: Rural group has the most expanded vowel space (maximum F2 /i/ and minimum F1 /i/) over. There is a centralized trend (tending to the center of the chart) observed in the IDP group, which occasionally may represent linguistic accommodation or a consequence of a language contact as the result of displacement.

**Figure 3 Magnitude Differences (Effect Size:  $\eta^2$ )**



In light of the given instances of visualization the analysis of the phonetic difference among the groups by using effects sizes ( $\eta^2$ ) and standardized mean differences follows:

a) Dominant Acoustic Markers

The chart "Magnitude of Differences" shows the most significant phonemic aspects that distinguish the groups:

- (1) F2 of /u/ (Backness): This is the strongest discriminating value, reaching a significant effect size ( $\eta^2 \approx 0.14$ ). It means that the horizontal position of the tongue for the vowel /u/ changes across the groups most radically.
- (2) F2 of /i/ (Backness): The second most significant differentiator with a medium-large effect ( $\eta^2 \approx 0.13$ ).
- (3) Vowels Height F1 /i/ and F1 /u/: Both indicate a medium effect size (0.06 to 0.10), which means that there is a significant difference in the amount high the tongue is raised in relation to these vowels.
- (4) Minimum Distinguishing Size: The pitch (Mean F0) and the backness of /a/ (F2 /a/) are the least distinctions and they do not reach the medium level.

b) Group-Specific Phonetic Biases

These differences can be viewed (in their specific direction) with the help of the heatmap:

**Table 7. Group-Specific Phonetic Biases**

Acoustic Variable	IDP Group Bias	Rural Group Bias	Urban Group Bias
Vowel Height (F1)	Consistently higher F1 (Lower tongue position) for all vowels.	Consistently lower F1 (Higher tongue position).	Near-zero bias; serves as the phonetic "baseline".
Vowel Backness (F2)	Lower F2 for /i/ and /u/, indicating more backed production.	Higher F2 for /i/ and /u/, indicating more fronted production.	Minimal bias, slightly leaning toward the global mean.
Pitch (Mean F0)	Strong positive bias (198Hz); speaks with higher pitch.	Strong negative bias (182Hz); speaks with lower pitch.	Slight negative bias (189Hz).

c) Key Phonetic Interpretations

- (1) IDP Group "Lowering" and "Backing": IDP group shows systematic change in the form of a more open mouth (higher F1) and a more retracted tongue (smaller F2). And it adds to the elevated pitch (Mean F0) can be this either a separate dialectal substratum, or a social linguistic adaptation to displacement.
- (2) Rural Group "Peripheralization": Rural group fronts their vowels more (by A lower F1) and earlier (higher F2). It is usually a more conservative or traditional form of articulation pattern with vowel contrast being maximized.
- (3) Urban Leveling: The Urban group has fewest standardized differences (shades of white/ light blue). This is an obvious case of the dialect leveling where the urban centers, which serve as a metropolis of phonetic extremes, consequently, soften the phonetic aspect of the rural or migrant populations.

Interpretation of the interview data through thematic analysis indicated three overall themes namely the linguistic adaptation as a survival strategy, the social meaning of phonetic change, as well as, the climate grief as a linguistic experience. The

respondents under the comprehensive IDP group showed a consistent temporal description of phonetic modification by indicating it to be a conscious or semi-conscious change in line with the new communicative conditions. One of the respondents (IDP-07, a male, 16 years) said: Although I first arrived at the camp, I used to speak like the people of the south [marshlands]. The children in this case were not able to comprehend certain words, so I began to speak in a different manner. Now I don't even think about it.

Social meanings to phonetic variation were found to be complicated and even contradictory. Participants explained phonetic convergence as a way of having social integration with camp peers and members of the host community, and some suggested that it helped to preserve original dialectal characteristics with ethnic identity and resistance to being displaced. One of the female participants (IDP-15, 18 years) told me: My accent is how I stay at home. When I speak like the folks back at home, I feel a part of it although I am distant.

The topic of climate grief as linguistic experience arose specifically in the participants who were displaced in areas of the marshlands. Depreciation of customary ways of living (fishing, buffalo herding, reed harvesting) was described by participants as something that was closely related to their perception of language identity. One of the respondents (IDP-22, male, 19 years) replied: My grandfather used to know the names of all the birds and fish in the marshlands. Anymore those words did not make any sense when we left. The spot on which those words dwelt is dead. This information provides a profound insight into the intercourse of sociolinguistics and environmental displacement. The thematic analysis brings out the point of explaining how language is not only a means of communication, but is also a psychological anchor and social means of survival.

The themes and the implication are examined herein:

1. The Survival Strategy of Linguistic Adaptation

The shift in conscious to the semi-conscious adaptation referred to by IDP-07 is a typical instance of Linguistic Convergence.

- a. Pressure of Accommodation: the participant modified his speech to make the communication less frictional. Misunderstanding in a camp environment may cause social isolation or bullying, adaptation is a survival mechanism.

- b. The Unconscious Shift: when one may not even think about intentionally initiating an action anymore (Now I don't even think about it), it is supposedly because of the high degree of neuroplasticity and the underlying desire to be a part of the new peer group.

2. The Phonetic Change: Social meaning

This motif underlines the dual nature of language in displacement that it is the bridge and the boundary at the same time.

- a. Integration vs. Resistance: You have taken a conflict between language use Instrumental (adjusting speech to fit in by adapting) and Integrative language use (maintaining speech to maintain contact with roots).

- b. Dialect as a Portable Homeland: For IDP-15, her accent acts out of reference to her village as the mental map of her village. Preserving a native accent in a new place is a language rebellion, in other words, the unwillingness to allow the displacement to completely seep away her origin.

3. Hidden Grief as Linguistic/Climate Grief

This is, maybe, the most distinctive and heartrending discovery. It reaches to the idea of Solastalgia- the sorrow of environmental change.

- a. Semantic Void: IDP-22 refers to a loss of reference. Due to the disappearance of the physical environment (marshes, birds, fish), special vocabulary to describe it loses its new home.
- b. Ecological Loss = Cultural Loss: This implies that the climate change does not only kill livelihoods, but also leads to linguistic exertion. Unless the language to describe buffalo herding or reed harvesting is employed because the practice has been abandoned, the language and the values that it holds will probably vanish in less than a generation.

The results of the current research support the notion of eco-phonetic adaptation in situations involving climate displacement, which proves that internally displaced learners display the systemic acoustic differences in respect to those who have not migrated. The trend in the outcomes indicates that displacement brings about environments that are favorable to phonetic change by a number of ways: accommodation to new dialectal settings, psychological stress reactions and the linguistic costs of environmental displacements. The changes in formant frequencies observed among the participants in IDP indicate changes in vowel quality in line with accommodation between dialect and stress-induced articulatory changes. The high values of F1 of the /i/ and /u/ vowel / in the participants of the IDP sample indicate that there is a tendency of centralizing of corner vowels, and this has been recorded in other situations of linguistic accommodation and the circumstances of cognitive load. This point of interpretation can be further justified by the patterns of the F2 variation, whereby the participants of the IDP would subsequently exhibit medium values which would imply some convergence to the urban norms.

The lower level of articulation among the participants of the IDP is a rather strong result that has a variety of possible interpretations. The decreasing speech rate can be interpreted as the cognitive load related to the multilingual conditions that demand the phonological observation, psychological strain reactions to the motor planning, or premeditated adaptation to the speech rates of interlocutors in the situation of multilingual communication. All the three interpretations are backed by the qualitative data, where participants reported about the cognitive requirements of the code-switching and psychological impact of the displacement on the speech production.

The results of the regression help to understand the predictors of phonetic variation among displaced people and state that the duration of displacement enables accommodating processes, whereas the exposure to language diversity increases acoustic variation. These results are in agreement with the predictions of the Accommodation Theory but they broaden the concept of the theory to include the unique circumstances of climate displacement. The correlation between exposure to the climate tragedy and the increase in fundamental frequency points to the idea that even the psychological aspect of the climate displacement is possible to have a measurable phonetic reflection. The qualitative results add a layer of interpretation to the quantitative results to show what is subjectively involved in acoustic variation. The accounts of phonetic change as a strategy of survival provided by participants bring light to the functional aspects of eco-phonetic change, and the descriptions of climate change as linguistic experience can inform our knowledge of the psychology underlying the relationships between the environmental loss with speech production.

The limitations of this study as far as the methodology is concerned should be noted. The cross-sectional design does not allow the formation of causal results about the

time process of phonetic change after displacement. Future studies need to utilize longitudinal designs that will monitor the phonetic development having followed the occurrence of displacement until the present. Also, the sample was selected in the Kurdistan Region camps, and it has to be studied why it can be generalized to other displacement exercises.

## CONCLUSION

This work serves as a building block of the currently emerging eco-phonetic research domain where systematic acoustical differences in the speech of internally displaced students in Iraq are recorded. The results indicate that the climate displacement creates quantifiable changes in the vowel formant frequencies, fundamental frequency and rate of articulation, and the pattern of the variation indicates the accommodation, psychological stress reaction, and the linguistic effects of environmental loss. Practical implications of this study would extend to the educational policy, speech-language pathology practice and integration period of uprooted people. The educational professionals that deal with students with IDP must understand that the phonetic variation is an adaptive mechanism to displacement as opposed to a language impairment to be fixed. SLPs working with displaced populations need to address the knowledge of eco-phonetic adaptation in their assessment and intervention procedures. The linguistic aspect of displacement needs to be considered in integration programming but avenues given to the displaced people to remain connected to their linguistic culture yet emerging with skills in lingua franca varieties.

Further studies need to be implemented to broaden this study to other displacement scenarios across the world in order to establish whether the trends experienced with the Iraqis population of the IDPs are applicable in other areas and the type of displacement. Longitudinal studies that follow phonetic change since displacement would help understand how eco-phonetic change occurs and how stable it is and experimental studies that alter the communicative conditions would support particular accommodation hypotheses. Moreover, the studies of the perceptions of listeners about eco-phonetic variation would shed more light on the social implications of phonetic change when it is imposed on a displaced person.

The interplay of climate change and human mobility is one of the issues of our time, whose linguistic impacts are yet to be given the appropriate focus by academics. This paper is part of the slowly growing trend of accepting the fact that in climate displacement, language is not just a means of communication, but also a field of experience that is closely linked with environment, identity and wellbeing. With a rapid process of climate displacement around the world, the linguistic aspects of this process are gaining recent brainstorming importance, and policy, practice, as well as underlying questions about how humans linguistically adjust to climate change, become more pressing.

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