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Examining the Use of PRAAT to Improve English Lexical Stress Production: Insights from Self-Directed Learning within the Framework of Self-Determination Theory

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Abstract

The study aims to examine how PRAAT visual feedback can improve pronouncing English lexical stress and support self-directed learning based on the conceptual framework of self-determination theory. The study involved a total of 80 EFL learners aged 18 to 22 years from Saudi Arabia and Yemen, with varying levels of English proficiency. Pre- and post-tests assessed the lexical stress phonetic features, namely duration, intensity, and fundamental frequency (F0), to evaluate pronunciation improvements. The study also conducted interviews to pinpoint the effect of PRAAT on the learner's autonomy, competence, and relatedness. Results showed significant enhancement in vowel duration, intensity, and F0 in the experimental group, indicating that PRAAT effectively supported the learners to improve production of English lexical stress. The improvements in vowel duration were more noticeable due to the clearer visual representation of duration measurement in PRAAT. However, vowel intensity and F0 showed varied enhancements based on the participants' proficiency levels. The interviews further highlighted the learners' autonomy, competence, and relatedness in improving their English pronunciation using PRAAT. The interview results shed light on individual needs and call for teachers' consistent directions. This study provides insights into the interplay of technology, pronunciation instruction, and learner autonomy, leading to more effective pronunciation learning.

Keywords: *PRAAT, English Lexical Stress, EFL Learners, Self-Directed Learning, SDT*

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Introduction

“It's /'wɜ:rkt/, not /'wɜ:rk'id/!”

A verbal scenario that frequently occurs in Arab EFL classrooms as a teacher attempts to develop English pronunciation.

Intelligible pronunciation is considered a crucial component of communication, which serves as the bridge between linguistic competence and comprehensibility (Mahdi & Mohsen, 2024; Park, 2020; Pennington, 2021; Tajeddin & Norouzi, 2024). Mastering pronunciation for EFL learners is essential not only for clear and accurate speech but also for successful interaction between a speaker and a hearer. According to Coppinger and Sheridan (2022) and Levis (2018), pronouncing a language with a non-native accent may have substantial psychological and social effects in communication with other speakers from different language backgrounds. In this regard, Huang and Hashim (2020) reported that Chinese tertiary EFL learners feel happy and confident when their English accent is clear and intelligible. Conversely, they reported that heavily accented speech makes them feel anxious and afraid of people's judgement (Huang & Hashim, 2020). A growing body of research emphasises the importance of producing intelligible English speech for successful spoken interaction (Ghosh & Levis, 2021; Koffi, 2021; Verbeke et al., 2025).

Regardless of the extensive research on pronunciation instruction (PI), EFL learners, including Arab EFL learners, continue to grapple with numerous challenges in achieving intelligibility in English pronunciation (Jahara & Abdelrady, 2021). These challenges affect learners' communication competence, which results in communication breakdowns (Ghosh & Levis, 2021). In the EFL context, teaching English pronunciation remains the stepchild of EFL education. While the 'Cinderella' metaphor, as described by Celce-Murcia et al. (1995), may have faded from common usage among scholars, it still aptly captures the marginalisation of pronunciation teaching in many EFL contexts. This persistent condition is thought to exist for a variety of reasons, including a lack of teachers' confidence in teaching pronunciation (Levis, 2022), learners' unwillingness to practice pronunciation and anxiety (Amoah & Yeboah, 2021), a lack of teachers' proper pronunciation knowledge (Levis, 2022), the impact of mother tongue (Syafutri & Saputra, 2021), or ineffective teaching practices and limited classroom time (Pennington, 2021).

Considering this issue from pronunciation teaching practices, EFL teachers provide greater emphasis on identifying English segmental pronunciation errors by EFL learners in classrooms (Rehman et al., 2022). According to Pennington (2021), the emphasis on segmental features means that teachers continue to use the "bottom-up" teaching approach, which is based on the concept that teaching segmental phonemes provides building blocks for language acquisition. In contrast, English suprasegmental features are essential for pronouncing words in the language correctly. Pennington (2021) further emphasised that the focus on suprasegmental aspects of a language is known as “top-down” orientation, which starts or concentrates on the highest levels of pronunciation to achieve more effective communication. However, EFL teachers give less attention to these features because teaching suprasegmental features is difficult due to their tangible nature, making them less observable to EFL learners. For example, when a student makes a pronunciation mistake in discriminating between /b/ and /p/ sounds, as in the case of Arab EFL learners (Al-khresheh, 2024), a teacher can simply write these sounds on the board and grab a piece of paper, explaining the vibration or the flow of air

that pushes the paper forward when the /p/ sound is pronounced. Meanwhile, pronunciation mistakes in suprasegmental features like stress are difficult to explain to EFL learners inside the classroom. As a result, a phenomenon known as foreign-accented speech is raised in this scenario, affecting speech intelligibility and potentially causing communication breakdowns (Levis, 2022).

The rapid application of technology to enhance language teaching and learning has sparked interest, known as Computer Assisted Language Learning (CALL). During this transition, Computer-Assisted Pronunciation Training (CAPT) introduced numerous technologies for language teaching and learning (Pennington, 2021). PRAAT, among others, is a technological software that provides acoustic sound features that have been developed and used for speech analysis (Koffi, 2021). The software has been used in English classrooms by several researchers to assist students in improving their pronunciation of the language, as demonstrated in the research conducted by Osatananda and Thinchana (2021) and Martin-Rubio (2021). These studies have highlighted the effectiveness of PRAAT in improving English characteristics in the classroom.

However, those studies did not provide in-depth insights into students' attitudes and motivations after utilising PRAAT to teach English pronunciation as opposed to traditional pronunciation instruction, particularly in terms of error visualisations. Prior research on teaching pronunciation has predominantly addressed the effect of using PRAAT on one level of proficiency, leaving room for discussion of whether the implementation may yield different outcomes if different levels of proficiency were involved in the same intervention. Pennington (2021) argues to examine the effect of PIs among different proficiency levels to find out the accurate instructions based on the learners' individual needs. Moreover, EFL teachers still plead for the insufficient time to teach English pronunciation in EFL classrooms, as highlighted in the study of Darcy et al. (2021). Therefore, this study suggests the implementation of PRAAT outside the classroom to reinforce self-directed learning guided by the principles of Self-Determination Theory (SDT) in an attempt to find a more effective way to learn English pronunciation, to solve the dilemma of timing, and to empower students to become more engaged and competent in their pronunciation learning.

While PRAAT is widely used for phonetic analysis and research in linguistics, and SDT focuses on motivational needs and the conditions that foster autonomous learning, there seems to be no direct connection established between the two in the literature. Therefore, this study investigates the interaction between the usage of PRAAT software, self-directed learning, and STD in order to improve Arab EFL learners' pronunciation of English lexical stress. To guide this inquiry, the study is structured around the following key questions:

RQ₁: How does the use of PRAAT software affect the production of English lexical stress among Arab EFL learners of different proficiency levels?

RQ₂: How do the aspects of competence, autonomy, and relatedness in self-determination theory, along with self-directed learning, influence the effectiveness of PRAAT software for English language learning?

Literature Review

Since 1955, scholars have argued over the value of English stress patterns used by EFL learners in improving their understanding of English speech recognition (Emara & Shaker, 2024; Koffi,

2021; Lee, 2024). Researchers concurred that diversity among languages' phonological and phonetic systems is the source of the debate towards the significance of the stress patterns in enhancing intelligibility while speaking the English language (Baagbah & Jaganathan, 2024; Koffi, 2021).

English stress patterns can be manifested at lexical and sentence levels. At the lexical level, stress occurs when one syllable in a word becomes more dominant than the other syllables (Baek, 2024). Such as the stressed syllable in the word **photograph**, the first syllable is more prominent than the other syllables. Coulange et al. (2024) state that lexical stress patterns play an important role in speech segmentation, word recognition, and lexical disambiguation. Similar conclusions have been drawn in recent studies, which found that effective stress placement in English speech enhances message intelligibility, improves listener comprehension, and facilitates more accurate word recognition (Emara & Shaker, 2024; Lee, 2024; Sañudo, 2024).

Producing English stress patterns is a natural process for native speakers, which involves the realisation of one or multiple phonetic cues such as duration, intensity, fundamental frequency (F0), and vowel formants. Studies reported that producing English lexical stress is challenging for English language learners, especially among speakers of languages characterised by uniform stress patterns in all lexical items, such as Arabic (Al-khresheh, 2024). Consequently, researchers have looked at how English lexical stress is acquired to gain a deeper knowledge of how EFL learners produce English lexical stress (Al-Khresheh, 2024; Emara & Shaker, 2024; Jaiprasong & Pongpairroj, 2020; Sañudo, 2024; Zuraiq & Sereno, 2021).

According to Altmann's (2006) Stress Typology Model (STM) and Liberman and Prince's (1977) Metrical Theory (MT), various languages display distinct rules and patterns of stress that are influenced by syllabic patterns and the existence of tense vowels. When learning English, EFL learners frequently struggle to produce English structures that differ from those of their native language. For example, learners may misplace stress or pronounce vowels incorrectly, which could result in misunderstandings if their L1 has distinct stress patterns or does not distinguish between tense and lax vowels as English does. In Metrical Phonology, Hayes (1995) proposed five parameters—dominance, boundedness, directionality, quantitative sensitivity, and extrametricality—that influence the differences in stress patterns across languages. Regarding the Arabic language, stress is predominantly attracted to syllables containing tense vowels; however, these syllables do not occur in the antepenultimate position. For example, in syllables with the structure CVVC.CV.CVVC, the initial heavy syllable, however, does not attract the primary (Bamakhramah, 2010, as cited in Baagbah & Jaganathan, 2024). This phenomenon is attributed to the syllable being considered extrametrical. However, extrametricality is not a feature of syllable structure in Standard Arabic. Consequently, Arab EFL learners may encounter challenges with extrametrical syllables that contain long vowels at the ultimate position. This can lead to a decrease in comprehensibility and challenges in communicating exact concepts, yet it also emphasises the need for focused instructional methods to address areas of difficulty and thereby enhance the pronunciation of the English language. Accordingly, Pennington (2021) reported that effective EFL instruction must address these cross-linguistic problems by providing explicit training on English stress and

vowel distinctions, compatible with learners' L1 backgrounds, in order to improve their overall language competency and communication skills.

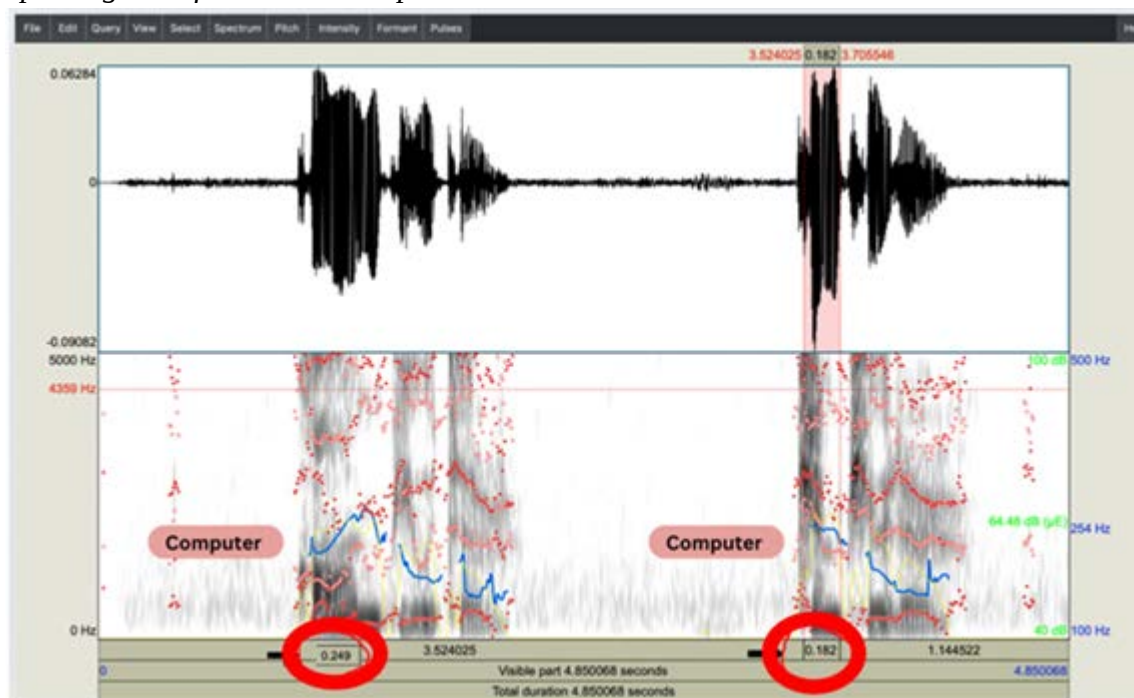
Pronunciation Instructions (PI) in EFL Classrooms

Despite the limited emphasis on teaching English pronunciation in EFL classrooms (Pennington, 2021; Mahmood, 2025), many EFL teachers primarily use traditional instructional strategies to address English pronunciation difficulties. For example, phonetic training is a basic method in which teachers use phonetic charts and symbols to assist students in producing certain sounds (Liu et al., 2022). This method combines direct instruction on how to articulate specific phonemes with practice, such as "ship" versus "sheep", to help learners improve their pronunciation. Drills and repetition are another common method of enhancing correct speech patterns (Mirzayev, 2024). However, there are many limitations that hinder the effectiveness of these methods, which are mostly caused by EFL teachers' insufficient phonetic knowledge, limited time frames, and the effect of mother influence on most of the EFL teachers' pronunciation (Nguyen & Hung, 2021; Pennington, 2021).

Recent advancements in technology have considerably changed the approach to language teaching, particularly in the realm of PIs. Using technology such as CALL and Automated Speech Recognition (ASR) systems has transformed how students practice and improve their English pronunciation (Thi-Nhu Ngo et al., 2024). These technological advancements facilitate personalised learning experiences where learners can practice pronunciation at a pace that suits them while receiving instant feedback tailored to their individual errors and learning needs (Ivanova, 2024; Pennington, 2021; Rogerson-Revell, 2021).

PRAAT software provides several benefits for pronunciation training. It enables learners to examine and display speech sounds, offering detailed information on pitch, duration, and formant frequencies (Bouchhioua, 2024). This software allows English learners to engage in instructional-specific phonetic practice, which can assist them in identifying and correcting pronunciation problems with a level of precision that traditional approaches do not provide.

Several studies investigated the use of PRAAT software to improve English pronunciation by learners of different language backgrounds (e.g., Al-Kinany & AlDighaishi, 2025; AlMuselhy, 2024; Osatananda & Thinchana, 2021; Rahmatunisa & Syarifudin, 2021). Results of these studies suggest integrating PRAAT software into pronunciation instruction to reduce pronunciation difficulties, particularly for EFL learners who face challenges with stress patterns and phonetic accuracy. PRAAT's significant feature of visualising pronunciation errors (by spectrograms and waveforms) allows learners to perceive detailed acoustic properties of their speech, such as pitch, duration, and formant frequencies (Osatananda & Thinchana, 2021). This function enables learners to recognise deviations from native speaker pronunciation and grasp how their pronunciation differs from target sounds. For example, a learner struggling with vowel length or stress patterns can compare their speech to that of a native speaker to identify particular areas for pronunciation improvement. The photo displayed in Figure 1 shows the spectrogram of the word computer, first pronounced by an EFL learner, followed by an American native speaker.

Figure 1*Spectrogram of the Word Computer Pronunciation*

It can be clearly seen that the duration measurements that are circled in red at the bottom of the spectrogram showed different measurements. The first vowel was longer in the production of the EFL learner as compared to the American native production of the same word.

Self-Directed Learning in Pronunciation Practices

Despite the benefits of PRAAT, a controlled classroom environment limits learners' ability to fully realise PRAAT's promise for autonomous practice and self-directed learning. The studies mentioned above have employed PRAAT under teacher supervision in classroom settings, which limits its potential for individual learner exposure. According to Lai et al. (2022), it is essential for students to engage in out-of-class and self-directed language learning, where they take control of their educational journey. Self-directed language learning in PIs is still underexplored in literature. Although communicative language teaching (CLT) enforces the idea of a student-centred approach inside the classroom, the frequent practices in the EFL context favour teachers controlling instructions inside and outside classrooms. In this regard, Nguyen et al. (2021) documented that Vietnamese EFL learners heavily rely on teachers to identify and correct their mistakes rather than solely depending on self-practice. Today's advancement in CAPT practices opens more chances for learners to practice their pronunciation independently. However, some teachers struggle with this transition because it challenges traditional classroom roles (Elmahdi & AbdAlgane, 2024). This issue could also be related to learners feeling incompetent or unable to practice English pronunciation on their own. As a result, it is critical to understand learners' motivation and attitudes on the use of CAPT independently.

Theoretical Underpinning

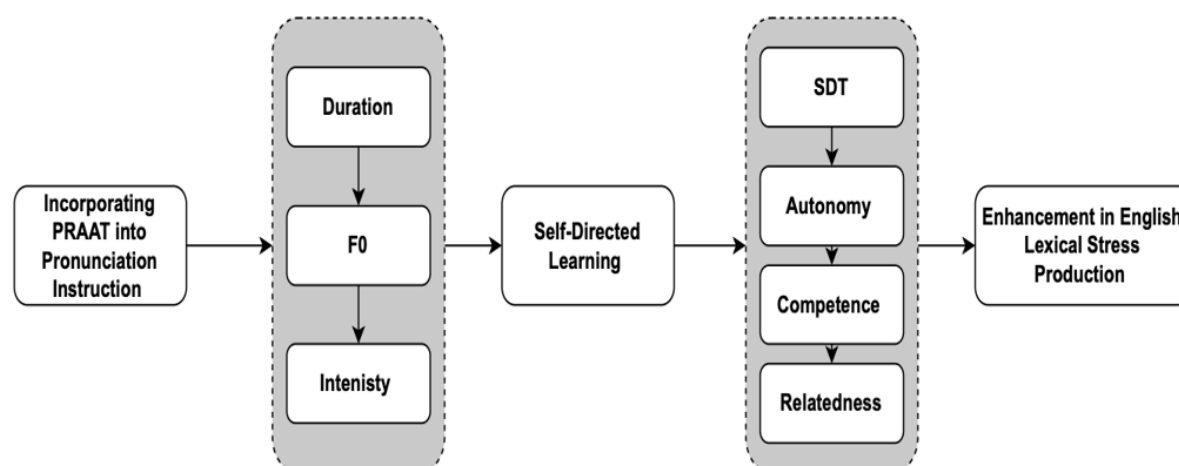
SDT offers a foundational framework that informs both instructional practices and broader educational reforms (Ryan, 2017; Ryan & Deci, 2020). The theory highlights three essential psychological needs that fuel learners' intrinsic motivation and autonomous engagement: autonomy, relatedness, and competence (Ryan & Deci, 2020). Competence, defined as the ability to effectively perform tasks or develop specific skills (Ryan, 2017), plays a pivotal role in encouraging students' active cognitive involvement. (Annamalai et al., 2023). Enhancing competency in the context of English lexical stress production by EFL learners using PRAAT software means giving students opportunities to foster their pronunciation skills through more effective guidance. In other words, it encourages students to continue participating in error-correction methods and to develop their enthusiasm to achieve more intelligible speech.

The desire for freedom or control over one's activities is known as autonomy, which is a psychological drive for independence that motivates students' behavioural involvement in class (Skinner et al., 2008). Learners who receive strong autonomy support are also more likely to find their lessons enjoyable (Zhu, 2024). Furthermore, autonomy is believed to boost cognitive engagement, yet research on instructional technology has not fully confirmed this concept (Bedenlier et al., 2020). By encouraging autonomy, PRAAT may empower learners to take charge of their pronunciation practice, increasing motivation, engagement, and overall satisfaction.

According to Ryan (2017), relatedness is the idea that one feels or perceives to be connected to other people. Several studies have demonstrated that learners' behaviours and emotional participation may be predicted by their sense of connectedness (Büssing et al., 2025; Shen et al., 2024). Creating a supportive learning environment is necessary to incorporate relatedness in the context of PRAAT and English pronunciation learning. PRAAT helps learners to visualise errors and compare them to the production of native speakers, which makes pupils feel engaged and connected. Teachers can foster learners' participation by attending to their needs. Once these three basic demands are met, learners' motivational perspective can shift from extrinsic to intrinsic motivation as they internalise their motivation progressively until they are motivated by something intrinsic to the activity.

The conceptual framework, as in Figure 2, shows that using PRAAT independently beyond the classroom might help learners gain confidence and improve their pronunciation competence.

Research in the field of language acquisition has focused on the psychological effects of technology affordances on learners (Jeon, 2022, pp. 1–26). This field of study can also help educators enhance the technical and pedagogical approaches in their language classes (Ruziyevna, 2025). Thus, prior to recommending PRAAT software to students as a tool to enhance their English pronunciation, it is recommended to look into its motivation and usage. To date, there has been no reliable evidence to examine the psychological requirements that arise when students use PRAAT to improve English pronunciation. Moreover, there has been limited research into the broader benefits of PRAAT's visual feedback for learner autonomy and pronunciation self-improvement. This study seeks to fill this gap by investigating how expanded learners' access to PRAAT, outside of the limits of teacher-led teaching, can improve pronunciation practice. Using the principles of Self-Determination Theory (SDT), which emphasises autonomy, competence, and relatedness.

Figure 2*Conceptual Framework of the Study***Method**

A sequential mixed-methods design was used to collect both quantitative and qualitative data. Pre- and post-tests were administered to assess the production of English lexical stress before and after the intervention. The pre-test involved a production task where participants read a word list (22 disyllabic and trisyllabic real words from the English File book), which were incorporated into carrier sentences, such as "I say defect." This approach was used to control the rhythm and minimise its impact on F0. The post-test consisted of 22 disyllabic and trisyllabic real words from the same book, carefully selected to have the same phonetic features (stress placement, vowel length, and syllabic pattern) as the pre-test words, but they are different words to avoid the familiarity effect. Refer to Appendix A for the stimuli of the study. The production of the participants was assessed by a phonetician using PRAAT software through the measures of vowel duration, intensity, and F0. Consequently, semi-structured interviews were also used in the collection of qualitative data.

Sample

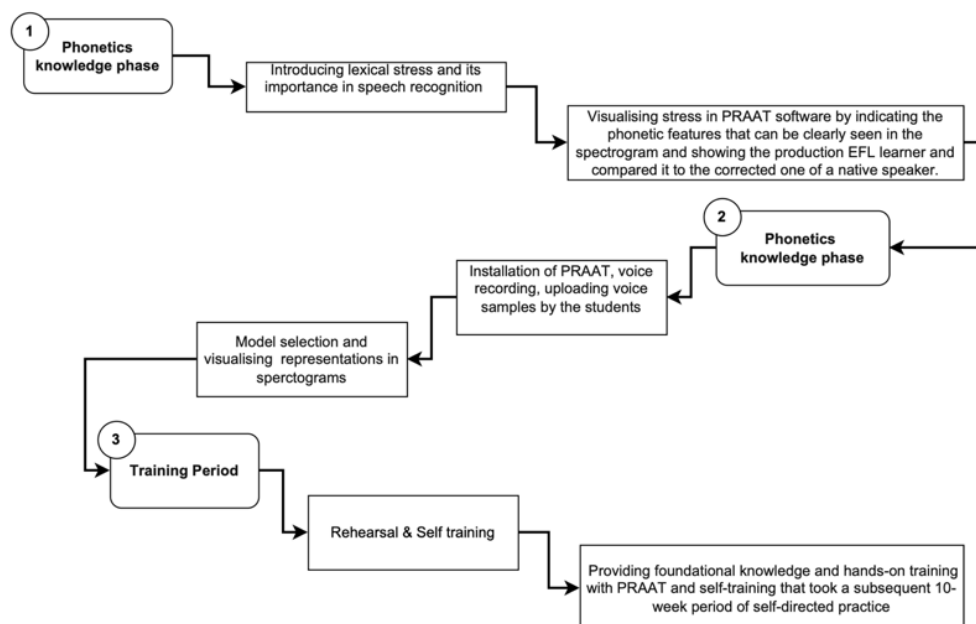
The study included 80 Arab EFL learners from Saudi Arabia and Yemen who were all enrolled in an online English language centre. The participants were aged between 15 and 22 years. They have varying levels of proficiency, including elementary (33), pre-intermediate (25), and intermediate levels (22). The learners' level was previously measured using the Great Language Centre's placement test (GLC), which is modelled after the Oxford Placement Test. The students received 90 minutes of English language for each online class on weekdays, using the "English File" textbook as part of their curriculum. The study was conducted online over a seven-month period with the goal of obtaining as many samples as the researcher could. To evaluate the impact of PRAAT software, the participants were divided into two groups: the experimental group (44 participants, 23 females and 17 males), who used PRAAT software for pronunciation practice, and the control group (36 participants, 18 females and 18 males), who received traditional instruction without the software. In addition, 10 participants from the

experimental group volunteered to participate in post-intervention interviews to provide qualitative insights into their PRAAT experiences and the impact on their pronunciation skills.

Intervention

The intervention designed for this study has adapted some procedures from a study conducted by Osatananda and Thinchab (2021). The procedures of the intervention comprised three essential stages aimed at enhancing English pronunciation among learners. First is the phonetics knowledge phase, where learners are given the instructional process a focus on emphasising the concept of English lexical stress. This aspect of phonetics is notably accessible through the PRAAT software, which allows learners to visualise and analyse stress patterns in spoken English. By understanding the role of stress in pronunciation, learners can improve their overall motivation for improving English pronunciation. Second is the PRAAT familiarisation period, which involved comprehensive training on the operation of PRAAT. This training included essential skills such as installation of PRAAT, voice recording, uploading voice samples, interpreting visual representations, and voice model selection. The instructional focus was on achieving intelligibility rather than striving for native-like pronunciation, reflecting a pedagogical shift as highlighted by Jenkins (2000). Learners were encouraged to explore various English accents available online and select speech samples that resonated with their personal preferences. In this context, the term "model" refers to the specific accent chosen for imitation, as defined by Brown (1991). This approach not only promotes autonomy but also allows learners to engage with diverse linguistic varieties, thereby enriching their learning experience. Third is the training period, which was structured in workshops that provided foundational knowledge and hands-on training with PRAAT and self-training that took a subsequent 10-week period of self-directed practice. During this phase, learners engaged in independent pronunciation practice using PRAAT. Refer to Figure 3 for the intervention procedures.

Figure 3
Intervention Procedures



Interview

To address the second research question, data were gathered through semi-structured interviews to understand factors related to SDT that influence self-directed learning of English lexical stress using PRAAT software. Cáceres (2003) emphasises that semi-structured interviews support both discourse and content analysis by enabling researchers to develop meaningful thematic categories, thus minimising misinterpretations and ensuring high validity. The development of the interview questions was informed by an extensive literature review on SDT and previous studies involving PRAAT implementation. The researcher adapted an initial set of questions from the study of Annamalai et al. (2023) aimed at exploring themes of competence, autonomy, and relatedness. Accordingly, 6 open-ended questions were developed based on the context and aim of the study. To validate the interview questions, a panel of 3 experts—comprising established researchers in technology, language, and phonetics—was consulted. Interviews were conducted via the video platform ZOOM, with each session lasting approximately 25 to 35 minutes. The interviews were recorded and transcribed word by word (verbatim), with follow-up questions posed to clarify participants' responses. Refer to Appendix B for the questions of the semi-structured interview. The data analysis followed Braun and Clarke's (2006) thematic analysis approach. Two primary coders were involved in identifying themes, with a third coder acting as a tiebreaker to resolve any discrepancies. Clear definitions of the codes were provided to ensure consistent application among coders.

The interview data were initially reviewed to generate early insights and detect emerging patterns. To systematically manage the data, a coding process was applied (Braun & Clarke, 2013), during which codes aligned with the researchers' focus and the phenomena under investigation were developed. It is necessary to note that the themes, which illustrate broader units of analysis, differ from the specific codes generated at this stage. The data analysis shifted towards classifying codes into potential themes. Each code was linked to a theme using a mind map approach (Braun & Clarke, 2006). The codes were consolidated into five main themes: competence, relatedness, autonomy, effectiveness of acoustic cues, and teaching activities (see Table 1).

To clarify the distinctions among the themes, the codes were revisited to ensure coherence and clarity (Braun & Clarke, 2013). The researchers revisited the data extracts to refine each theme and ensure that the narrative remained internally consistent and aligned with the overall findings (Braun & Clarke, 2013). This thematic analysis aligns with the study's objectives by providing insights into how SDT influences self-directed learning and the effective use of PRAAT software to improve the production of English lexical stress by EFL learners.

Table 1*Themes and the Categories of the Thematic Analysis*

Themes and Categories	Frequency
Competence	
Impact on English language competence	35
Mastery of lexical stress	30
Independent pronunciation tasks	28
Autonomy	
Comfort in managing PRAAT interactions	27
Influence of autonomy on motivation	32
Self-directed learning experiences	29
Relatedness	
Interaction with content	25
Support from teachers	20
Effectiveness of Acoustic Cues	
Importance of duration	20
Importance of intensity	15
Importance of fundamental frequency (F0)	18
Suggested Teaching Activities	
Integration of PRAAT into teaching	33
Support for self-directed learning	31

Results*Results of RQ1*

The first question aimed to assess the impact of PRAAT software on the production of English lexical stress among Arab EFL learners. A multivariate analysis of pre-test and post-test scores was conducted, focusing on three key acoustic measures: duration, intensity, and F0. Refer to Table 2 for the results of the multivariate test.

Table 2*Results of Multivariate Test*

Group	Measure	Pre-Test Mean	Post-Test Mean	p-value	Pillai's Trace	Wilks' Lambda	Hotelling's Trace	Roy's Largest Root
Experimental Group	Duration (ms)	250	230	< 0.01	0.68	0.32	4.25	3.85
	Intensity (dB)	65	70	< 0.05	0.60	0.40	3.50	3.20
	F0 (Hz)	150	160	< 0.01	0.65	0.35	4.00	3.75
Control Group	Duration (ms)	260	255	0.25	0.02	0.98	0.12	0.10
	Intensity (dB)	63	64	0.35	0.03	0.97	0.15	0.12
	F0 (Hz)	148	149	0.40	0.01	0.99	0.08	0.05

Based on Table 2, the experimental group showed significant improvements in all measures. The mean duration reduced from 250 ms in the pre-test to 230 ms in the post-test, with a p-value less than 0.01. This reduction suggests improved pronunciation effectiveness, implying that students articulated stressed syllables more efficiently after utilising PRAAT.

The average intensity increased from 65 dB to 70 dB, reaching statistical significance with a p-value of less than 0.05.

However, intensity was recognised as the least enhanced acoustic feature, showing that while intensity improved, it did not change as much as duration and F0. The mean of F0 increased from 150 to 160 Hz, with a p-value less than 0.01. In contrast, the control group exhibited no significant changes across all measures. The mean duration decreased from 260 ms to 255 ms, with a p-value of 0.25, showing no significant improvement in pronunciation. Similarly, the intensity slightly increased from 63 dB to 64 dB, with a p-value of 0.35, indicating a lack of significant enhancement over traditional methods of instruction. The F0 likewise exhibited little variance, rising from 148 Hz to 149 Hz with a p-value of 0.40. Table 3 shows results of the pre- and post-tests based on the participants' level of proficiency.

Table 3

Pre-Test and Post-Test Results by Proficiency Level

Proficiency Level	Measure	Pre-Test Mean	Post-Test Mean	p-value
Intermediate	Duration (ms)	280	260	< 0.05
	Intensity (dB)	60	65	< 0.01
	F0 (Hz)	140	150	< 0.01
Pre-Intermediate	Duration (ms)	240	230	0.12
	Intensity (dB)	65	70	< 0.05
	F0 (Hz)	150	160	< 0.01
Elementary	Duration (ms)	220	215	0.05
	Intensity (dB)	70	75	< 0.01
	F0 (Hz)	160	170	< 0.01

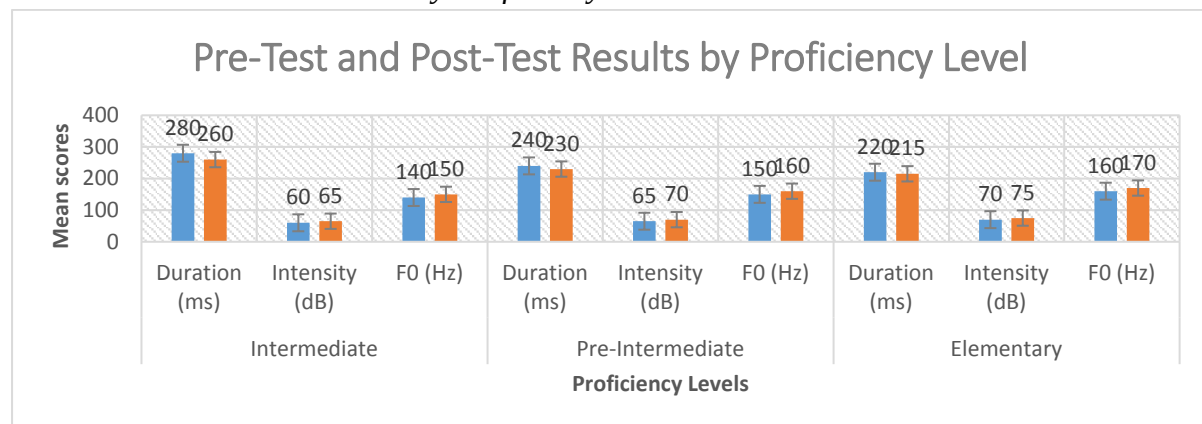
The results of the pre-test and post-test based on the three proficiency levels—elementary, pre-intermediate, and intermediate—show measurements of improvements in pronunciation of English lexical stress acoustic cues. At the intermediate level, participants produced shorter duration from 280 ms to 260 ms ($p < 0.05$), increased intensity from 60 dB to 65 dB ($p < 0.01$), and raised F0 from 140 Hz to 150 Hz ($p < 0.01$), resulting in more accurate production of English lexical stress.

At the pre-intermediate level, duration remained consistent (240 ms to 230 ms, $p = 0.12$), but intensity increased from 65 dB to 70 dB ($p < 0.05$), and F0 rose from 150 Hz to 160 Hz ($p < 0.01$), indicating improved loudness and pitch control. For the elementary level, duration decreased slightly from 220 ms to 215 ms ($p = 0.05$), while intensity improved from 70 dB to 75 dB ($p < 0.01$) and F0 increased from 160 Hz to 170 Hz ($p < 0.01$), indicating a balanced improvement in duration, loudness, and pitch. The same results are illustrated in Figure 4. Table 4 shows the results of the post-hoc test to find out if there are any significant differences among the three levels.

Table 4*Results of the Post-Hoc among the Three Levels*

Comparison	Measure	Pre-Test Mean	Post-Test Mean	p-value
Elementary vs. Pre-Intermediate	Duration (ms)	280 vs 240	260 vs 230	< 0.05
	Intensity (dB)	60 vs 65	65 vs 70	< 0.05
	F0 (Hz)	140 vs 150	150 vs 160	< 0.01
Elementary vs. Intermediate	Duration (ms)	280 vs 220	260 vs 215	< 0.05
	Intensity (dB)	60 vs 70	65 vs 75	< 0.01
	F0 (Hz)	140 vs 160	150 vs 170	< 0.01
Pre-Intermediate vs. Intermediate	Duration (ms)	240 vs 220	230 vs 215	0.12
	Intensity (dB)	65 vs 70	70 vs 75	< 0.01

Significant differences were identified in duration, intensity, and F0, indicating that pre-intermediate learners performed better in terms of stress placement and F0 control than elementary students. There were major variations in duration, intensity, and F0, with intermediate learners outperforming elementary learners in producing the three phonetic measures. Significant variations in intensity and F0 indicate that intermediate learners performed better than the pre-intermediate learners in intensity and F0 control, although duration was not significantly different.

Figure 4*Pre-Test and Post-Test Results by Proficiency Level*

Results of RQ2

The participant interviews revealed insightful information about their experiences with PRAAT and how it affected their ability to pronounce English, especially in terms of mastering lexical stress. The results found a number of major themes that reflected aspects of Self-Determination Theory (SDT) and were in line with the study's objectives.

Competence

Most of the participants reported notable enhancements in producing English words as a direct result of using PRAAT software. Participants 1, 5, and 7 had a significant sense of fulfilment, pointing out how the software improved their pronunciation accuracy and confidence. They emphasised that PRAAT helped them detect and practice stressed syllables more efficiently,

which they said was critical to increasing their fluency. For example, participant 5 stated that *"My previous teacher only mentioned to us the stressed and unstressed syllables, which made me always confused, and I didn't even recognise why it was important. I used to say it was useless. But now, I could finally see the differences in stress patterns, which helped me to recognise the idea better and improve my speech."*

In contrast, participants 9 and 24 provided more evaluation on their improvement. While they acknowledged the usefulness of PRAAT, they indicated that they still struggled with certain aspects of pronunciation, suggesting that the software was not a complete solution for their challenges, as stated by participant 24, saying, *"The biggest difference is recognising the differences between my pronunciation and the correct one, but I sometimes become confused with the visualisation of the wave file because they sometimes become similar, but the measurement is different. So, I always need my teacher for more guidance."*

Autonomy

The concept of autonomy was mentioned frequently, with many participants reporting confidence in managing the use of PRAAT. Participants 11 and 2 appreciated the software's usefulness, which allowed them to practice at their own pace and schedule. They related this feeling of control to an improved desire for pronunciation practice, with Participant 7 saying, *"Being able to choose when and how to practice made a huge difference for me. I feel more confident now because I can practice and check my speech on my own and take the time that I need."* However, Participant 9 expressed some concerns about feeling overwhelmed at times due to a lack of formal instruction. This suggests that, while autonomy is often regarded as positive, it can sometimes provide difficulties for learners who want more guidance. As such, participant 9 said, *"I enjoyed it, but I needed my teacher's help very often during the intervention period. I felt more capable and trusted when I was with the teacher."*

Relatedness

Although the interviews did not focus on social interactions, several participants highlighted how important instructor assistance is when using PRAAT. Participants 1 and 24 discussed how teachers' advice and encouragement built a sense of belonging, making them more ready to experiment with self-directed learning software. For them, the teachers' support served as a motivator, increasing their involvement in PRAAT. In contrast, Participant 7 took a more self-sufficient attitude, saying, *"I felt I could navigate PRAAT independently without much help..."* This belief implies that some learners may thrive in a more autonomous environment, which emphasises the consideration of individuals' needs.

Effectiveness of Acoustic Cues

Regarding the effectiveness of the phonetic cues, participants consistently chose duration as the most important component in improving their English lexical stress. Participants 5 and 24 both reported that the duration had a direct impact on their comprehension, with Participant 24 commenting, *"Duration made the biggest difference for me. It is very clear because I can directly see it under the wave file. So, I can make my production shorter and closer to the model speaker."*

Most of the participants indicated that mastering duration in pronunciation greatly improved their ability to be understood. While intensity and F0 were seen as useful, they were considered secondary to duration. For example, participant 5 said, *“I feel intensity and F0 are more complicated because they can be easily changed based on how I say the whole sentence. I prefer duration measurement to check.”* This result demonstrates that learners have a strong preference for focusing on specific audio signals that directly contribute to their pronunciation skills.

Suggested Teaching Activities

Participants made a variety of suggestions for how teachers could better integrate PRAAT into their instructional approaches. Participants 13, 17, 23, and 4 advocated for an organised strategy that blends software use with traditional teaching approaches, such as incorporating PRAAT into regular pronunciation exercises. They hoped that this would result in a more effective learning experience. Participant 17 said, *“It will be very interesting to have homework that can be submitted in spectrogram photos or video, which will make doing homework fun and engaging.”* Participant 9, on the other hand, emphasised the need for creative PRAAT applications, arguing that gamifying the learning process might increase engagement and make practice more pleasurable. In this regard, participant 9 said, *“We can do many creative activities with PRAAT to improve our pronunciation. One activity that came to my mind is that we can PRAAT karaoke by mimicking a native speaker and see which one of us gets it closer.”* Participant 23 said, *“We can do spot the differences and highlight the mistakes from the spectrogram. This will show if we understand or not.”* This range of suggestions can provide teachers with many activities to adjust their instruction based on student needs. Based on the interview results, the researchers obtained deeper insights into individual differences in those who may require additional effort and continuous assistance to improve viable and engaged self-independent learning.

Discussion

The findings of this study shed light on the effectiveness of PRAAT software in enhancing English lexical stress production, particularly through measurable improvements in duration, intensity, and fundamental frequency (F0). Participants who engaged in PRAAT training demonstrated noticeable gains in their pronunciation performance, suggesting that the visual and acoustic feedback provided by the software contributed meaningfully to their learning process. This result is in line with earlier studies, including those by AlMuselhy (2024), who reported the positive impact of PRAAT on the development of segmental and suprasegmental pronunciation features among EFL learners.

A major strength of PRAAT lies in its ability to visualise pronunciation errors through the use of spectrograms, waveforms, pitch tracks, and intensity curves, as explained by Koffi (2021). These tools allow learners to observe the acoustic properties of their speech, specifically, how pitch, duration, and formant structure deviate from native speaker norms. By enabling learners to compare their own speech output with model forms, PRAAT encourages active noticing and self-correction, which are key elements in pronunciation acquisition. This aligns with the claim that pronunciation difficulties can be reduced when

learners are provided with clear, immediate, and multimodal feedback, especially in contexts where traditional instruction may be insufficient (Nguyen & Hung, 2021; Pennington, 2021).

Moreover, this study provides new insights into the reduction of vowel duration in unstressed syllables following the intervention. This finding is particularly significant, as it implies an improvement in the learners' ability to produce accurate lexical stress patterns. In English, vowel duration is a salient feature of stress, with stressed vowels typically being longer and more intense than their unstressed counterparts (Baek, 2024). Many Arab EFL learners, however, tend to produce equally timed syllables and lengthen vowels inappropriately, influenced by the rhythmic and phonological features of Arabic, where vowel length is phonemic but less variable according to stress (Zurairq & Sereno, 2021). As a result, they often fail to convey the stress patterns that are critical to intelligibility in English. As such, the post-intervention data suggest that PRAAT helped learners overcome these challenges by making acoustic contrasts, particularly in vowel duration, visually salient. By comparing their vowel productions to the target forms shown on the spectrogram, learners could perceive the temporal differences between stressed and unstressed vowels. This exposure likely enhanced their phonological awareness, enabling them to adjust their articulation accordingly.

The findings also revealed a measurable increase in intensity, though it was the least significant acoustic improvement among the three parameters analysed. Despite its relatively lower effect size, this enhancement is noteworthy, as it indicates that learners became more capable of producing stressed syllables with greater vocal energy, a feature that plays a crucial role in marking prominence and conveying meaning in spoken English. Intensity, alongside duration and F0, contributes to the perceptual salience of stress, and even subtle improvements in this area reflect learners' growing control over suprasegmental features. Moreover, the results concerning fundamental frequency (F0) were particularly significant. Participants demonstrated the ability to modify their pitch contours appropriately to mark lexical stress, an area known to be problematic for Arab EFL learners. These findings directly address the concerns raised by Zurairq and Sereno (2021), who argued that learners from Arabic-speaking backgrounds often face considerable challenges in producing accurate F0 cues due to the phonetic constraints inherent in Arabic, where pitch variation does not function as a primary marker of stress. Notably, this difficulty persists across proficiency levels, making it a persistent obstacle in EFL pronunciation development.

However, the study provides empirical evidence that such limitations can be overcome through targeted and acoustic-based training. This evidence supports using CALL and ASR systems in enhancing and improving EFL learners' pronunciation (Thi-Nhu Ngo et al., 2024). Specifically, learners were not only able to interact with the PRAAT software but were also successful in transferring their pitch modifications to meaningful pronunciation tasks, such as stress placement in multisyllabic words and controlled speaking exercises.

Results based on learners' proficiency levels revealed notable differences in how the intervention was perceived and its outcomes. Specifically, intermediate-level learners recorded higher mean scores across all PRAAT measurements, duration, intensity, and F0, suggesting that they benefitted more from the training compared to their lower-proficiency peers. However, this finding should not be interpreted as a direct indication of the superior effectiveness of the PRAAT intervention alone. As Levis (2021) rightly notes, increased exposure to English can contribute significantly to learners' ability to perceive and produce

prosodic features more accurately. Therefore, proficiency level serves as a mediating factor that may influence the extent to which learners are able to utilise and benefit from technologically supported PI.

The implications of this result emphasise the importance of differentiating pronunciation instruction based on learners' proficiency levels. Designing interventions to suit learners' linguistic backgrounds and developmental stages can yield more substantial improvements. Intermediate learners may be more receptive to the detailed visual-acoustic feedback provided by PRAAT, as they likely possess a greater phonological awareness and metalinguistic knowledge, which enables them to interpret and apply feedback more effectively. In contrast, lower-level learners might require more foundational support, scaffolding, or simplified tasks before they can fully benefit from the same instructional tools. In line with this, Pennington (2021) has emphasised the need for further research that systematically investigates how PI functions across varying levels of proficiency. Understanding which types of instruction are most effective for learners at different stages of development is essential for optimising pronunciation pedagogy. The current study supports this call by showing that while PRAAT can be beneficial across proficiency levels, its impact may not be uniform, and differentiated instruction could enhance learning outcomes more equitably. As such, future research and instructional design should consider adaptive frameworks that align PRAAT-based activities with learners' specific proficiency levels, ensuring both accessibility and effectiveness.

To further explore the motivational dimensions influencing the effectiveness of PRAAT as a self-directed pronunciation learning tool, semi-structured interviews were conducted with selected participants. The qualitative data revealed several significant themes that contributed to understanding learners' experiences with PRAAT in pronunciation instruction. Overall, the majority of participants expressed positive attitudes toward the software, noting that PRAAT allowed them to better perceive and analyse their own pronunciation errors, particularly in the areas of duration, intensity, and fundamental frequency (F0). These visual-acoustic cues provided concrete feedback that empowered learners to independently diagnose and modify their pronunciation output, an approach that aligns with the tenets of SDT (Ryan & Deci, 2020), which highlights the role of competence, autonomy, and relatedness in motivating learners and enhancing performance.

Participants reported that PRAAT made the abstract nature of lexical stress visible and measurable, thus bridging the gap between theoretical knowledge and practical application. As learners gained the ability to visually compare their own productions with target models using spectrograms and waveforms, their understanding of lexical stress patterns and acoustic variability improved. This finding supports previous studies (e.g., Ivanova, 2024; Pennington, 2021), which emphasise that explicit pronunciation training combined with acoustic feedback can lead to greater accuracy and learner awareness.

Nevertheless, individual differences emerged in learners' motivational responses to using PRAAT. While many participants felt a heightened sense of control and ownership over their learning, particularly those with intermediate proficiency, some learners—especially at lower proficiency levels—found the software overly technical or difficult to use without guidance. Participants 9 and 24, for instance, expressed that PRAAT, while beneficial in theory, did not fully meet their learning needs due to a lack of foundational linguistic knowledge or confidence. These responses highlight the importance of scaffolding pronunciation

instruction when integrating technological tools, especially for learners with limited phonological awareness (Levis, 2021). This observation echoes Pennington's (2021) call for differentiated PI that adapts to learners' proficiency levels and learning styles.

Moreover, a recurring theme in the interviews was the value of autonomy in pronunciation practice. Participants 5 and 7 described how PRAAT enabled them to practice at their own pace, revisit difficult sounds, and take control of their learning trajectory—factors that increased their intrinsic motivation and engagement. This is in line with research by Zhu (2024), who argue that fostering learner autonomy and offering flexible learning opportunities enhance self-regulated learning in pronunciation. However, as Participant 9 pointed out, complete autonomy may not be ideal for all learners, and greater instructional structure and clearer learning pathways may be required to ensure optimal outcomes. This supports Liu et al. (2022), who suggest the need to explore how technology can support clear pedagogical design by teachers and instructors.

Although the interview data did not emphasise relatedness in terms of peer interaction or collaborative learning, teacher encouragement was cited as a significant motivator for sustained engagement with PRAAT. Several learners noted that positive reinforcement from instructors encouraged continued use of the software, reinforcing their sense of achievement and direction. This finding reinforces the "relatedness" component in SDT, where teacher-student rapport and perceived support are crucial for maintaining motivation in language learning contexts (Ryan, 2017). Conversely, Participant 7 reported thriving independently without the need for such support, which suggests variability in learners' motivational profiles and highlights the importance of personalised instruction and learner-centred approaches (Pennington, 2021).

Another important theme emerged around the relative importance of different acoustic cues. Most participants perceived duration as the most salient and helpful feature for improving lexical stress. Learners indicated that changes in vowel length were easier to perceive and replicate, making duration a more intuitive cue than intensity or F0. This aligns with Koffi (2021), who asserts that duration is often the most critical and teachable acoustic correlate for stress in English, particularly for learners from syllable-timed language backgrounds such as Arabic. While intensity and F0 were acknowledged, they were often viewed as less immediately accessible and thus may require more explicit instruction and targeted practice.

Based on these findings, this study yields several practical implications for language educators, curriculum designers, and teacher trainers. Firstly, the findings suggest that PRAAT can be effectively integrated into pronunciation instruction, especially for teaching lexical stress. Teachers should receive training on how to design PRAAT-based tasks that are pedagogically sound, manageable, and tailored to learners' proficiency levels. Ready-made templates and guided tutorials can make PRAAT more accessible to both instructors and learners. Secondly, since intermediate learners benefitted more from the intervention, instructors should consider differentiating pronunciation instruction. For lower-level learners, scaffolding and simplified tasks are crucial. Blending PRAAT with more conventional teacher-led explanations and demonstrations may increase its effectiveness for beginners. Thirdly, PRAAT encourages self-directed learning and gives learners control over their practice. Teachers should cultivate autonomy-supportive environments by allowing learners to choose

practice times, focus on personally challenging sounds, and self-assess using visual feedback. This aligns with Self-Determination Theory (Ryan & Deci, 2020), and can foster greater intrinsic motivation. Fourthly, as learners found duration to be the most intuitive and effective cue for stress production, instructors might prioritise this feature in early training phases. Teaching materials should include exercises focused on manipulating vowel length and contrasting stressed/unstressed syllables using PRAAT visualisations. Fifthly, for lower-proficiency learners who struggle with independent technology use, hybrid instructional models that combine PRAAT with guided classroom activities or synchronous feedback from instructors may be more effective. This also allows for peer collaboration and instructor scaffolding, meeting the diverse motivational and cognitive needs of learners.

While the findings of this study provide meaningful insights into the effectiveness of PRAAT as a self-directed pronunciation learning tool for Arab EFL learners, several limitations should be acknowledged. First, the sample size was relatively small and limited to a specific population of learners from similar linguistic and educational backgrounds. Therefore, the generalisability of the findings to broader EFL contexts should be made with caution. Second, the study primarily focused on lexical stress, specifically duration, intensity, and F0, without addressing other suprasegmental features such as intonation, rhythm, or connected speech, which also play a critical role in intelligibility. Third, while participants engaged with PRAAT over a specific intervention period, the study did not measure long-term retention or transferability of pronunciation gains to spontaneous speech or real-life communicative contexts. In terms of delimitations, the study was confined to Arab EFL learners and did not include comparisons with learners from other L1 backgrounds. It also limited its scope to the use of PRAAT software as the primary tool for pronunciation training, excluding other pronunciation technologies such as AI-powered applications or virtual reality platforms that may offer different affordances.

Future studies can expand on this research by employing larger and more diverse participant samples, including learners from different L1 and cultural backgrounds, to examine cross-linguistic influences on the perception and production of stress. Moreover, longitudinal studies could investigate the sustainability of pronunciation improvements and assess how PRAAT training influences learners' real-world speaking performance over time. Comparative studies between PRAAT and other pronunciation technologies (e.g., ELSA Speak, ChatGPT, or mobile apps with AI feedback) would also be valuable to determine the relative efficacy of different instructional tools. Finally, researchers should explore how specific learner characteristics, such as learning style, motivation profile, and technological literacy, interact with pronunciation tools to shape learning outcomes.

Conclusion

The study aimed at investigating the role of PRAAT as a self-directed tool to improve EFL learners' production of English lexical stress. It also examined the motivational needs that may affect the utilisation of PRAAT by learners from different proficiency levels. Findings positively suggest the use of PRAAT inside and outside classrooms. Pedagogically, teaching pronunciation with PRAAT can be beneficial in improving pronunciation, as it visualises pronunciation mistakes, which increases their comprehension; therefore, their pronunciation gets improved. However, consistent guidance should be adhered to strike a balance between

using technology and learners' individual needs. Based on the findings of the interviews, PRRAT can be used through innovative practice rather than just feedback and instructions. Teachers can use PRAAT as a karaoke tool, shadowing model speech to improve prosodic features and connected speech. Theoretically, interview data revealed that pronunciation learning processes can be more empowered with self-directed learning via PRAAT software. This process facilitates SDT motivating aspects of relatedness, competence, and autonomy. This study therefore provides important insights into the effects of technology in the field of language education, particularly in pronunciation. It recommends that advanced integrated tools such as PRAAT will facilitate improvement in the proficiency and involvement of learners. Further research is needed to explore the effect of technological software on improving learners' pronunciation of different proficiency levels using differentiated instructions to gain practical insights into teaching pronunciation inside classrooms.

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Competing Interests

No, there are no conflicting interests.

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Appendix A

Pre-Test and Post-Test Words in Carrier Sentences

Pre-Test Word	Pre-Test Carrier Sentence	Post-Test Word	Post-Test Carrier Sentence
Import	I say import.	Export	I say export.
Decide	I say decide.	Defend	I say defend.
Attempt	I say attempt.	Collect	I say collect.
Attend	I say attend.	Project	I say project.
Record (noun)	I say record.	Contest	I say contest.
Repeat	I say repeat.	Reform	I say reform.
Insist	I say insist.	Assist	I say assist.
Present (noun)	I say present.	Permit	I say permit.
Address (noun)	I say address.	Process	I say process.
Protect	I say protect.	Connect	I say connect.
Important	I say important.	Immediate	I say immediate.
Exciting	I say exciting.	Exploded	I say exploded.
Delicate	I say delicate.	Complete	I say complete.
Activity	I say activity.	Difficulty	I say difficulty.
Confident	I say confident.	Compliant	I say compliant.
Education	I say education.	Decoration	I say decoration.
Fantasy	I say fantasy.	Discovery	I say discovery.
Adventure	I say adventure.	Adventure	I say adventure.
Economy	I say economy.	Authority	I say authority.
Electricity	I say electricity.	Identity	I say identity.
Responsibility	I say responsibility.	Necessity	I say necessity.
Activity	I say activity.	Variety	I say variety.

Appendix B

Interview Questions

Instructions:

The following interview questions are designed to gather insights about your experiences with using PRAAT software to improve your English lexical stress. Your responses will help us understand how PRAAT has influenced your learning process. Your feedback will be highly valuable in assessing the impact of PRAAT on self-directed pronunciation learning.

The interview questions included:

1. How has using PRAAT impacted your English language competence, particularly in mastering lexical stress?
2. In what ways does PRAAT enhance your ability to complete pronunciation tasks related to lexical stress independently?
3. How comfortable do you feel managing your interactions with PRAAT for English learning?
4. How does this autonomy influence your motivation to practice pronunciation?
5. Which acoustic cue—duration, intensity, or fundamental frequency (F0)—do you find most effective in helping you improve your English lexical stress through PRAAT? Why?
6. How would you like your teachers to incorporate PRAAT into their teaching activities to support your self-directed learning in mastering pronunciation?