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Restructuring Consonant Accuracy in Functional Phonological Disorders: OT-Based vs. Traditional Therapy in Jordanian Arabic-Speaking Children

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Abstract

This study evaluates the efficacy of an Optimality Theory (OT)-based intervention versus a traditional phonetic-motor approach in treating Functional Phonological Disorders (FPDs) among Jordanian Arabic-speaking children. Thirty children (ages 3; 0-6; 11) diagnosed with FPDs were randomly assigned to two therapy groups. Over 12 weeks, the OT group received constraint-reanalysis activities designed to re-rank markedness and faithfulness constraints, while the traditional group engaged in articulation drills. Outcomes were measured in Percent Consonant Accuracy (PCA) and error-pattern reduction at post-treatment and three-month follow-up. Results indicate significantly greater gains in the OT group (PCA | from 35% to 82%) than in the traditional group (PCA | from 38% to 65%), with superior maintenance at follow-up (78% vs. 55%). These findings support OT's theoretical and clinical utility in phonological intervention.

Keywords: Optimality Theory (OT); Functional Phonological Disorders (FPDs); Phonetic-Motor Approach; Jordanian Arabic; Sustainable Speech-Language Intervention.

1. Introduction

Functional Phonological Disorders (FPDs) appear in the form of systematic speech patterns that tend to deviate, and which occur without recognizable organic reasons. Children who have FPDs often have replacements, omissions or assimilations, including deleting final-consonant, cluster reduction, and fronting, which undermine intelligibility and may negatively influence academic achievement and social functioning (Bernhardt and Stemberger 2000). In Jordan, FPDs have long been evaluated and treated using phonetic-motor means of assessment and intervention, where repetitive exercises, modeling, and physical feedback are utilized with the emphasis on the physical production of the independent phoneme (Dodd, 2005). Phonetic-motor approaches can be successful in generating quick improvements in context-free production of isolated sounds, but they generate context-specific improvements that might not extend into untrained phonological contexts or be sustainable over time (Gierut 2001).

A major development in the phonological theory came with the introduction of Optimality Theory (OT) by Prince and Smolensky (1993), which modelled language as a consequence of conflict between

universal, violable constraints. Instead of producing phonological representations by a sequence of rules, OT assumes that surface orders are the result of the optimal attainment of ranked constraints; markedness, which disfavors complex or undesirable structures, and faithfulness, which maintains the integrity of the input. Within clinical settings, this framework proposes an influential incentive through which phonological disorders are comprehended and treated because it enables a practitioner to prioritize underlying grammatical patterns instead of only errors presented on the surface. For instance, Gierut (1998) and Gierut & Morrisette (2011) have shown that constraint-based therapy, particularly when targeting complex or later-acquired sounds, leads to greater system-wide phonological change. OT-based approaches also support the use of minimal pairs, maximal oppositions, and complexity-based selection, strategies that have been empirically validated to promote generalization (Barlow & Gierut 2002).

Further on, Barlow (2001) demonstrated that OT offers a strong explanation of variable error patterns that traditional linear models fail to explain. By incorporating the production variability into the analysis, clinicians can refine the interventions that take into account both the accuracy and the frequency of errors resulting in individual, more effective therapy. Therefore, by re-ranking these constraints, especially when atypically prioritized in children with phonological impairments, clinicians can promote broader, more systematic changes across a child's sound system.

OT offers an alternative, constraint-based paradigm that conceptualizes phonological competence as the outcome of interactions among universal, violable constraints (Prince & Smolensky 1993; McCarthy & Prince 1995). Within this framework, GEN generates candidate outputs for a given input, CON ranks markedness constraints (which penalize disfavored structures, e.g., CODA, *COMPLEX) against faithfulness constraints (which preserve input-output correspondence, e.g., MAX, DEP), and EVAL selects the optimal candidate that best satisfies the hierarchy. In children with FPDs, unusual constraint rankings (i.e. high ranking of CODA relative to MAX) result in expected errors such as final-consonant deletion. Interventions involving OT then seek to have constraints re-prioritized in terms of faithfulness, reformatting the underlying phonological grammar of the child, as opposed to focusing on articulatory output.

Although there is an increasing focus on OT as a clinical phonology theoretical model (Bailey and Hahn, 2001; Inkelas and Rose 2007), the available literature comparing OT-based therapy and traditional phonetic-motor work is still limited, especially in non-Western dialectal contexts. Being rich in consonants and dialectally specific phonotactical structures, Jordanian Arabic proves to be a challenging language to assess and to intervene in (Abu-Taha 2008). A constraint-based diagnostic package and intervention program designed to address the needs of Jordanian Arabic could not only enhance the clinical outcomes in the area, but also advance the cross-linguistic validity of OT-based interventions.

To this end, the research question in this study is as follows: How does an OT-based intervention compare to traditional phonetic-motor therapy in enhancing consonant accuracy among Jordanian-speaking children with FPDs? And what are the most phonological errors most appropriately addressed with the OT-based therapy?

Following this question, the current study will discuss various dimensions of phonological intervention, which are critical in the context of Jordanian Arabic, with an objective to connect the theory

and practice in a culturally and linguistically determined environment. First, it analyzes both the immediate effectiveness of each approach and the extent of generalization to the untreated phonological environment, an aspect that is necessary in real world communicative competence. Second, it examines the sustainability of treatment gains as time goes by, and as this is what matters in the long term in terms of academic success and social interaction of children. Third, placing the study in the context of the Arabic language of Jordan, which is characterized by emphatic, pharyngeal, uvular consonants as well as multifaceted consonant group systems, it assesses whether constraint-based reanalysis processes are better-adapted to language-specific phonotactic constraints than articulatory exercises. Lastly, the study examines the metalinguistic awareness and involvement in children during the therapeutic process in view of the fact that metacognitive requirements of OT-based activities can mediate motivation and learning achievement in contrast to more repetitive characteristics of traditional exercises. Together, these dimensions provide an overall picture of how and why various therapeutic paradigm produce different patterns of changes in phonological systems.

2. Literature Review

Functional phonological disorders (FPDs) are speech disorders that involve systematic deviations from age-appropriate speech norms, which cannot be attributed to identifiable organic causes (Bernhardt & Stemberger 2000). These disorders usually present themselves as substitutions, omissions, or assimilations of speech sounds, making speech unintelligible in social as well as academic areas. Dodd (2005) reported that children with FPDs have not only communication problems hampering their interaction with the society and their schoolwork, but also emotional problems. This is important because therapies designed to mitigate the adverse effects of these disorders on child development require early diagnosis and intervention in clinical practice (Alqhazo and Alkhamaiseh 2025).

Phonetic motor therapy has traditionally been used, based on ideas from motor learning for FPDs. Typically, these therapies encourage repetitive articulatory drills to improve motor precision of specified phonemes. To facilitate accurate articulation of speech sounds, clinicians frequently employ structured modeling, multisensory feedback, and perceptual training tasks that enhance auditory discrimination and motor control, reflecting principles outlined in motor-based treatment strategies for speech sound distortions (Preston et al. 2020). They are taught to make articulatory adjustments step by step in a controlled fashion through these methods. Although phonetic motor therapies may produce rapid improvements in the accuracy of targeted sounds, these gains frequently remain context-specific and do not readily generalize across the phonological system (Maas et al. 2008). Additionally, these gains are usually temporary and do not last (Gierut 2001). The limitation of this generalization is that although children might have made progress on particular sounds in the clinical environment, they have difficulties applying these changes in their general speech which is integral to adequate communication.

While phonetic and motor approaches to treatment are offered, constraint-based models, such as OT, provide a better explanation of phonological competence, and a different treatment approach (Prince & Smolensky 1993; McCarthy & Prince 1995). According to OT, phonology is the result of the interaction

of universal constraints of markedness and faithfulness constraints. The faithfulness constraints enforce the preservation of input output correspondence and penalize loss and melodiousness that does not occur (MAX, DEP), while Markedness constraints penalize the phonological structures that are less common or less favored as a language, like CODA, COMPLEX, etc.

Based on OT, phonological errors committed by children with FPDs are regarded because of misranking these constraints. Such reranking of a child's constraints allows one to restructure the underlying phonological grammar, which produces more generalized changes across multiple phonological contexts (Inkelas & Rose 2007). In fact, there is research exploring how OT based intervention approaches can lead to more durable phonological change. For example, Gierut et al. (1996) discovered that OT informed treatment led to increased transfer to untreated sounds and system-level phonological intervention has been shown to promote generalization beyond trained targets in Spanish-speaking children, with improvements extending to untreated sounds and contrasts (Williams 2006). The emphasis placed on the re-ranking of constraints by OT can subsequently result into more extensive and enduring enhancements of phonological competence.

Recent research also emphasizes on the cross-linguistic relevance of intervention based on OT. OT-informed intervention has been shown to promote wider phonological generalization, with gains extending to untreated sounds and structures, underscoring the model's predictive and therapeutic value in clinical phonology (Gierut 2007). More recently, Btoosh (2006) investigated OT-driven remediation for complex onset clusters in Levantine Arabic. They reported significant improvements not only in the sounds that were trained but also in previously untreated structures. This emphasizes the model's predictive and therapeutic utility in specific dialect contexts.

Although OT has been quite successful in improving the traits of disorders in Indo-European languages, research in phonological disorders in Arabic has lagged, with research typically being limited to descriptive phonetics and phonological analysis (Amayreh 2003). Studies employing minimal pairs therapy have consistently reported improvements in consonant accuracy (Weiner 1981), and the consonantal system of Saudi Arabic provides a suitable basis for applying minimal contrast approaches (Ingham 1994). However, as was seen with traditional phonetic motor therapies, these studies were limited to the extent that generalization was reported to untreated phonological environments. Furthermore, the literature that exists on Arabic phonology relates to variation between dialects, and these variations have great influence on the efficacy of different intervention methods. For example, Jordanian Arabic constitutes a very detailed consonantal inventory in addition to various phonotactic constraints (Watson 2002), which makes it different from other Arabic dialects. Therefore, Jordanian Arabic provides speech-language pathologists with challenges in treating children with FPDs.

Since this study examines phonological intervention in children who use Jordanian Arabic, there is a strong need to situate the study within the developmental phonology of Jordanian Arabic. There are several early researches that have recorded the patterns of acquisition of Arabic phonemes among normally growing children, especially in terms of consonant accuracy and the syllable structure. Amayreh and Dyson (1998, 2000) in particular gave detailed descriptions of the developmental trend of Arabic consonants and provided normative data on the phonetic inventories and the articulatory mastery of

consonant development among various age groups. Their results emphasize the comparative sequence of pharyngeal, emphatic, and uvular parts, which is specifically pertinent to the typology of Jordanian Arabic. The more recent work of Mashaqba, Huneety, and other researchers has given fixations to this direction of study by considering specific segmental and prosodic effects in Jordanian Arabic. These include studies on the acquisition and representation of geminate consonants (Mashaqba et al. 2021), the production of multisyllabic words (Huneety et al. 2023), and the acquisition of emphatic consonants (Mashaqba et al. 2022).

These studies provide a strong developmental baseline against which phonological disorders can be assessed. By grounding the current comparative intervention study in this body of literature, it becomes possible to distinguish between developmentally appropriate error patterns and those that may require clinical intervention, thereby enhancing both the theoretical and applied dimensions of the research.

However, this paper fills the most critical gap in the literature for a controlled comparison of OT-based interventions against traditional phonetic motor therapies in the context of Jordanian Arabic. This study not only provides information regarding the relative effectiveness, generalizability, and treatment gain maintenance of both therapeutic approaches for children with FPDs but also contrasts and evaluates these two approaches of therapy in a non-Western and dialect-specific treatment setting. The results of this study can contribute to theoretical debates in clinical phonology and to evidence-based practices of speech language pathologists with Arabic speaking populations. This study contributes to the general area of phonological intervention research by underscoring the usefulness of adopting a phonologically analytic system to phonological intervention based on the known phonological characteristics of Jordanian Arabic, and what these requirements necessitate regarding the implementation and design of treatment protocols.

3. Methodology

3.1 Participants

Thirty Jordanian Arabic-speaking children (18 males, 12 females) aged between 3; 0 and 6; 11 years were recruited from the speech-language pathology clinic at Al-Ahliyya Amman University-Jordan. The mean age of the children in the study was 4 years and 9 months, while the standard deviation was one year and 2 months (M = 4; 9, SD = 1; 2). Inclusion criteria comprised: (a) a clinical diagnosis of a Functional Phonological Disorder (FPD) with no concomitant organic or neurological impairments; (b) performance at least 1.5 standard deviations below age norms on a standardized articulation screening; and (c) normal hearing, as confirmed by audiological screening within the previous six months. Children receiving concurrent language or cognitive interventions were excluded. Thus, all participants were monolingual speakers of rural Jordanian Arabic, specifically representing dialectal features typical of non-urban communities in central and northern Jordan. Parental consent and child assent were obtained in accordance with the Institutional Review Board of Al-Ahliyya Amman University.

3.2 Design and Assignment

A randomized controlled design was employed. Participants were randomly assigned (using a computer-generated sequence) to one of two intervention groups (n = 15 per group):

1. The first group: OT-Based Intervention

2. The second group: Traditional Phonetic-Motor Therapy

Group assignment was concealed from assessors to minimize bias; clinicians delivering the treatments were aware of group membership but did not participate in outcome assessments.

3.3 Intervention Protocols

3.3.1 OT-Based Intervention:

Duration: Twelve weekly sessions, each lasting 45 minutes.

Focus: Constraint-reanalysis activities designed to shift the child's constraint hierarchy. Key components included:

Constraint Identification Tasks: These are the guided tasks where kids can be made aware of the phonological limitations that apply in their language. As an example, pairs of words of which some were phonotactically appropriate and others were phonotactically deviant were presented to them and asked to name the ones that sounded correct in their Jordanian dialect (e.g., *batta* vs. *banta*). This exercise increased the awareness of the acceptable sound structures and implicitly brought about markedness limitations.

Re-ranking Exercises: Structured phonological data had been presented to the children and they were requested to predict or evaluate the forms of output in connection with various input conditions. By having to discuss their outputs with peers and be provided with tutor feedback, they were given unconsciously to consider why some of their outputs took precedence over others, thus implicitly learning about the ways in which various constraints can be given precedence (or deemphasized) in the Optimality Theory to create the correct target forms. In this way, interactive games that demand the choice or creation of forms that prefer faithfulness constraints to markedness constraints (e.g., preservation of final consonants).

Metalinguistic Reflection: Following the phonological practice, the children engaged in reflexive conversations where they gave reasons as to why they thought some words were correct or incorrect. These sessions helped them think out loud and explain their reasoning in a way that fostered the emergence of metalinguistic awareness and made them internalize phonological rules and processes. Pattern discussion (e.g., Why does "bat" retain its /t/? What happens when we attempt to say two consonants at the beginning of a word? These reflective deliberations were done using a simple language, which was age-appropriate and sometimes aided by giving visual aids or making gestures to drive internalization of re-ranked constraints. These sessions were used to bring phonological awareness beyond that of mere repetition so that the child will internalize the rules either in terms of sonority sequence or syllable sequence by expressing the rules in his or her own words. The reflective process did not only improve learning but also linked clinical exercises to the high-level objectives of the Optimality

Theory-based intervention, in which the key point is to comprehend the mechanism of constraint interaction and repair plans.

Traditional Phonetic-Motor Therapy:

Duration: Twelve weekly sessions, each lasting 45 minutes.

Focus: Articulatory precision through:

Repetitive Drills: Repetitive Drills: The therapist modeled target forms (e.g. /s/ in *samaka*) repeatedly and asked the child to imitate them in different contexts (e.g., *samak, sami, sina*). This repetition helped reinforce articulatory patterns and placement of phonemes. It also reinforces Isolation, syllable, and word level practice of target consonants (/k, g/: clusters).

Tactile Kinaesthetic Cues: Kinaesthetic Tactiles Cues: these methods included touching the throat of the therapist as the child was encouraged to experience the vibrations of voicing, and touching their fingers that will go along their own face to feel the air move and the position of the lips. This method helps in realizing the sensitivity of sound production especially in fricatives and stops. Precise articulatory movements are formed by the use of manual instructions and visual modeling.

Auditory Discrimination: Children were given minimal pairs (e.g., *samak* vs. *θamak*) and asked to identify which word matched a picture or was correctly pronounced. This assisted in training their auditory processing in order to differentiate related phonemes. Comparison between incorrect and correct productions were done in listening tasks.

3.4 Outcome Measures

• Primary Measure: Percent Consonant Accuracy (PCA)

The consonant accuracy was evaluated through a 100 item picture naming task which involves all the consonantal phonemes as well as a standard variety of syllable structure. In the pictures, there are all 28 consonantal phonemes of Jordanian Arabic and a representative variety of syllables (CV, CVC, CCV, CVCC, etc.). The choice of target words was done on the basis of age-level vocabulary and phonemic balance to cover popular phonological conditions and word locations (initial, medial, final). The complete list of items utilized in the task is given in Appendix A. The audio recordings of productions were phonetically transcribed and observed by two independent, blinded assessors; the inter-rater reliability was higher than 95%. The 100-item picture-naming test was designed with sufficient attention to the phonemic inventory and syllable construction of the Jordanian Arabic, not neglecting their cultural and developmental suitability to the target age. This is in line with the principles of need-based material design, which focus on linguistic possession and learner-needs content (Al-Shallakh 2025).

Secondary Measure: Error Pattern Inventory

The number and types of phonological error patterns (e.g., final consonant deletion, cluster reduction, fronting) were tallied for each child at each assessment point.3.5 Assessment Timeline

Evaluations occurred at four time points:

Baseline (Pre-Treatment)

Mid Treatment (Week 6)

Post Treatment (Week 12)

Follow Up (3 Months Post Treatment)

3.6 Data Analysis

Statistical analyses were conducted using SPSS v.26. Repeated measures ANOVAs examined group (OT vs. Traditional) x time (Pre, Mid, Post, Follow Up) effects on PCA and error patterns. Where significant interactions emerged, post hoc Bonferroni-corrected pairwise comparisons identified specific time point differences. Effect sizes (e2) were reported to quantify the magnitude of group differences. Significance was set at $\alpha = .05$.

4. Results and Discussion

4.1 Percent Consonant Accuracy (PCA)

A repeated measures ANOVA was conducted to assess the impact of intervention type (OT-based vs. traditional phonetic-motor therapy) on the Percent Consonant Accuracy (PCA) scores at pre-treatment, mid-treatment, post-treatment, and follow-up stages. The analysis revealed a significant main effect of time, $F(3, 84) = 45.23$, $p < .001$, $\eta^2 = .62$, indicating overall improvements in PCA across all participants. Importantly, there was a significant interaction between time and treatment group, $F(3, 84) = 5.72$, $p = .001$, $\eta^2 = .17$. Post-hoc comparisons showed that both groups demonstrated significant improvements from pre-treatment to post-treatment (OT-based: $p < .001$; Traditional: $p < .001$), but the OT-based group showed a significantly greater increase in PCA at post-treatment (M = 72.5%) compared to the Traditional group (M = 60.3%) (p = .002).

At the three-month follow-up, the OT-based group maintained a high level of accuracy (M = 70.2%), while the Traditional group showed a decline in accuracy (M = 58.9%) from post-treatment levels (p = .03). The difference in PCA between the two groups was statistically significant at follow-up, $t(28) = 2.46$, $p = .02$, indicating superior long-term retention in the OT-based group.

4.2 Error-Pattern Inventory

The error patterns (e.g., final consonant deletion, cluster reduction, and fronting) were also assessed across time points. A repeated measures ANOVA revealed significant reductions in error-pattern frequencies for both groups over time, $F(3, 84) = 38.42$, $p < .001$, $\eta^2 = .57$. However, the OT-based group showed a significantly larger reduction in error patterns at post-treatment and follow-up compared to the Traditional group (p = .04). Specifically, error patterns such as final consonant deletion and cluster reduction, which were prevalent at pre-treatment, showed greater normalization in the OT-based group at post-treatment and follow-up. The Traditional group, while demonstrating improvement, still exhibited residual error patterns at follow-up, particularly with final consonant deletion (p = .05).

4.3 Group Comparisons

The results suggested that the OT based group had significant improvements in all measured outcomes and to a greater extent, generalization to untreated sounds followed at the follow up evaluation.

Despite their effectiveness in obtaining targeted consonants, however, the Traditional group had less generalization to other phonological structures. Post treatment comparison between groups also showed that the OT-based group produced more consistent phonological accuracy across the different contexts (p = .01). However, the Traditional group improved in target contexts only, and without marked improvement in untreated phonological forms.

This study was aimed to evaluate the effectiveness of OT-based interventions relative to speech letter for increasing consonant accuracy and altering phonological error patterns in Jordanian Arabic speaking children with FPDs. The results suggest that the OT based method showed a greater rate of gains in percent consonant accuracy (PCA) and more reduction of error patterns in comparison to traditional methods. These results are in line with other studies which show that constraint-based approaches; that is speaking to the child's underlying phonological grammar rather than just having them motorically manipulate their articulators, may lead to greater and longer lasting gains than traditional motor approaches for treating children with phonological disorders (Gierut & Morrisette 2012).

5. Dialect-Specific Error Examples

Several phonological error patterns are observed among children with FPDs who speak Jordanian Arabic. These Phonological errors are closely tied to dialect-specific features. One of the most prominent patterns was final consonant deletion, which is particularly marked in Jordanian Arabic due to the phonotactic importance of word-final consonants. As an illustration, the word /ʔalb/ "heart" often occurred in the form of [ʔab], with the loss of the /l/ component of the final consonant cluster. The error will lead to a notable decrease in word intelligibility and is able to impact morphological differences in connected speech.

Cluster reduction which was common especially in initial and medial positions was another common pattern. Jordanian Arabic enables the usage of numerous complex consonants groups in comparison with other dialects. The typical example was the word /kta:b/ "book" in which children simplified the cluster /kt/ to [t] so as to obtain [ta:b], which marks a failure to control the marked constraint *COMPLEXONSET. Such error was observed in items of untreated groups of the traditional therapy but was significantly reduced in the OT-based treatment group.

Children also displayed glottal substitution of pharyngeal or uvular sounds which are characteristic of Jordanian variety. The word /ʕejn/ ("eye") for example was pronounced [ʔejn], the pharyngeal /ʕ/ replaced by glottal stop [ʔ], avoiding marked articulatory features that are usually not handled in phonetic-motor drills. The OT-based therapy helped in the constraint re-ranking that prevented such substitutions by favoring faithfulness constraints such as IDENT[place].

These examples suggest ways in which dialect specific phonological structures interact with developmental constraints and highlight the need for intervention models, such as OT, that take into consideration linguistic characteristics of the target dialect. The fact that OT-based approaches can generalize improvements to these types of errors gives clinical significance for its application in diverse Arabic-speaking populations.

In this study, several error patterns were prominent pretreatment and these were more effectively addressed by the OT based intervention than by phonetic motor drills:

Final-Consonant Deletion (FCD):

Target: /kalb/ "dog" [kalb]

Pre-Treatment Errors: [kab] (FCD)

OT Group Post-Treatment: 14% occurrence of FCD

Traditional Group Post-Treatment: 46% occurrence of FCD

Cluster Reduction (CR):

Target: /kta:b/ "book" [kta:b]

Pre-Treatment Errors: [ta:b] (initial cluster reduction)

OT Group Post-Treatment: 10% CR

Traditional Group Post-Treatment: 38% CR

Velar Fronting:

Target: /ʔakl/ "food" [ʔakl]

Pre-Treatment Errors: [ʔatl] (fronting of /k/ → [t])

OT Group Post-Treatment: 8% fronting

Traditional Group Post-Treatment: 29% fronting

These examples represent the influence of OT-based therapy. By re-ordering the markedness constraint CODA below faithfulness (MAX) and *COMPLEX below DEP, we will have more effective and more consistent results than drills alone in maintaining final consonants and clusters.

The OT based group had a better maintenance of treatment gains at the three months follow up with the PCA being maintained at 78 percent when it came to targeted consonants and untargeted contexts, compared to 55 percent in the Traditional group. This result confirms the assumption that the variability of phonological accuracy can be more enduring, especially when OT serves to restructure phonological rules, as opposed to drill into the exact forms of sound. Although traditional phonetic motor therapy is effective in improving the accuracy of trained speech sounds, such approaches often yield limited generalization across phonological contexts and reduced long-term retention, outcomes that are characteristic of segment-specific drills (Williams, McLeod, and McCauley 2021).

Moreover, the decrease in error patterns, especially the final consonant deletion and cluster reduction were greater in the OT based group, which can be supported by the fact that constraint reranking allows a more extensive reorganization of the phonological system of a child. The Traditional group, on the contrary, revealed the residual error patterns at a follow-up, particularly in complex clusters such as /kl/ and /kt/.

The current study will contribute to the existing literature on the use of phonological interventions on Arabic speaking children, which is a field that is still under defined research. Jordanian Arabic, which has some of the richest repertoire of emphatic and pharyngeal consonants (e.g., /ṣ/, /ħ/.), has special clinical and therapeutic problems. In comparison to the previous studies centered on Indo European languages or the neighboring dialects of Jordan (e.g., Saudi Arabic; Aljuhani, 2022), the study provides the first empirical study of the OT based and traditional phonetic motor therapy in the Jordanian setting.

6. Conclusion

The findings of this research show that OT-based intervention is superior to the traditional phonetic-motor intervention to enhance consonant accuracy and eradicate phonological error patterns among Jordanian Arabic speaking children with FPDs. This highlights the contribution of the focus of OT on re-ordering fundamental phonological limitations in inducing not only the more generalized improvements outside the structured treated phonological processes, but also more lasting treatment effects. The traditional phonetic motor approach, on the contrary, were efficient to improve articulation accuracy on targeted sounds but failed in generalization and without long-term effects. This study fills the gap in the literature on phonological interventions for Arabic speaking children by comparing the comparative efficacy of OT-based and traditional phonetic-motor therapies in the context of a non-Western, dialect specific setting. This also offers support for the uses of constraint-based therapies in facilitating more comprehensive phonological changes that go beyond individual phonetic drills.

Findings further suggest that interventions focused on restructuring phonological rules result in an improvement that surpasses that of articulatory 'surface level' intervention in terms of sustainable performance, and superior performance of the OT group, especially in reduction of error patterns like final consonant deletion and cluster reduction. Based on these findings, speech language pathologists working with Arabic speaking children may choose to use OT-based approaches when performing therapy with these children. But more research is needed to examine the long term effects of such interventions and to generalize their applicability to other Arabic Dialects and other phonological processes aside from consonant accuracy. Besides, the follow up time and seeking new varieties of linguistic features will further illustrate the effectiveness of OT-based treatments in long term correction of FPDs. Finally, this study demonstrates the importance of applying such theoretical models as OT into clinical practice and offers new perspectives of the evidence based phonological intervention which is linguistically and culturally acceptable.

7. Limitations and Future Directions

A limitation that may arise in this study is the relatively short follow up period (three months). The sustainability of the treatment effects of more complex phonological processes would be better determined by longer term studies. Moreover, although this research had a focus on consonant accuracy and reduce errors pattern, future studies might extend the focus to the vowel systems, prosodic, and narrative skills to understand the general effectiveness of OT based interventions to determine the overall effectiveness of communicative competence.

Furthermore, although this paper closely relies on a constraint-based phonological theory to guide clinical intervention, emerging fields of interdisciplinary research provide promising opportunities on the involvement of computational models. As an illustration, Yaseen et al. (2025) show that the use of the linguistic intervention form of the vector-based semantic modeling can be used to recreate it, which can further provide a computational perspective of the phonological processes in question. These frameworks

can subsequently be used in future work to help in automated diagnosis or therapy planning by transforming sound patterns to formal representations.

Finally, the findings of the present research indicate that the interventions developed by OT can be of a better long-term value to children with FPDs, especially in encouragement of their generalization to the untreated phonological structures and their maintenance across time. The study suggests the relevance of applying theoretical frameworks, such as OT, in clinical practice and advises further investigation into the dialect specific applications in wide phenomena of Arabic phonology.

إعادة تنظيم دقة الصوامت في اضطرابات النطق الوظيفيَّة: دراسة مقارنة بين التدخل العلاجي القائم على نظريَّة الأمثليَّة والعلاج التقليدي لدى الأطفال الناطقين بالعربيَّة الأردنيَّة

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الملخص

تسعى هذه الدراسة إلى تقويم فاعليَّة تدخل علاجي قائم على نظريَّة الأمثليَّة (Optimality Theory, OT) مقارنةً بالنهج التقليدي القائم على التدريب الحركي-الصوتي في علاج اضطرابات النطق الوظيفيَّة لدى الأطفال الناطقين بالعربيَّة الأردنيَّة. شملت العينة ثلاثين طفلًا تتراوح أعمارهم بين 0;3 و11;6 سنوات، تم تشخيصهم باضطرابات النطق الوظيفيَّة، وجرى توزيعهم عشوائيًا على مجموعتين علاجيتين. على مدى اثني عشر أسبوعًا، خضعت مجموعة نظريَّة الأمثليَّة لأنشطة إعادة تحليل القيود بهدف إعادة ترتيب قيود السمة والأمانة، في حين تلقت المجموعة التقليدية تدريبات نطق مفصليَّة، قيست النتائج باستخدام مؤشر نسبة دقة الأصوات الساكنة (PCA) ومستوى انخفاض أنماط الأخطاء بعد العلاج مباشرةً. وفي متابعة بعد ثلاثة أشهر، أظهرت النتائج تحسنًا أكبر بشكل دال إحصائيًا لدى مجموعة نظريَّة الأمثليَّة (ارتفاع PCA من 35٪ إلى 82٪) مقارنةً بالمجموعة التقليديَّة (من 38٪ إلى 65٪)، مع استمرارية أفضل للتحسن في مرحلة المتابعة (78٪ مقابل 55٪). وتدعم هذه النتائج الأهمية النظرية والتطبيقية لنظرية الأمثلية في التدخل العلاجي الصوتي.

الكلمات المفتاحيَّة: نظريَّة الأمثليَّة (*OT*)؛ اضطرابات النطق الوظيفيَّة (*FPDs*)؛ المنهج الحركي-الصوتي؛ العربيَّة الأردنيَّة؛ التدخل المستدام في علاج اضطرابات النطق واللغة.

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Appendix A. Picture-Naming Task Items

Num.	Word (Arabic)	Gloss	Target Consonant(s)	Syllable Structure
1.	بطة	duck	/b/, /ṭ/	CVC-CV
2.	جمل	camel	/dʒ/, /m/, /l/	CVCVC
3.	باب	door	/b/	CV:C
4.	تفاح	apple	/t/, /f/, /ħ/	CVC-CVC
5.	حبل	rope	/ħ/, /b/, /l/	CVC
6.	طاولة	table	/ṭ/, /w/, /l/	CV:-CVC
7.	خبز	bread	/x/, /b/, /z/	CVC
8.	دلو	bucket	/d/, /l/, /w/	CVC
9.	سمكة	fish	/s/, /m/, /k/	CVCVCV
10.	ضرس	molar tooth	/ḍ/, /r/, /s/	CVC
11.	قلم	pen	/q/, /l/, /m/	CVCVC
12.	غزال	gazelle	/ɣ/, /z/, /l/	CVCVC
13.	عنب	grapes	/ʕ/, /n/, /b/	CVCVC
14.	موز	banana	/m/, /w/, /z/	CVC
15.	يد	hand	/j/, /d/	CVC
16.	كلب	dog	/k/, /l/, /b/	CVC
17.	أرنب	rabbit	/ʔ/, /r/, /n/, /b/	CVCVC
18.	بيت	house	/b/, /t/	CV:C
19.	سيف	sword	/s/, /f/	CV:C
20.	نحلة	bee	/n/, /ħ/, /l/	CVC-CV
21.	مدرسة	school	/m/, /d/, /r/, /s/	CVCVCVC
22.	دب	bear	/d/, /b/	CVC
23.	نور	light	/n/, /r/	CV:C
24.	ثعلب	fox	/θ/, /ʕ/, /l/, /b/	CVCVC
25.	ساعة	clock	/s/, /ʕ/	CV:ʕa
26.	ذهب	gold	/ð/, /h/, /b/	CVCVC
27.	وردة	flower	/w/, /r/, /d/	CVCVC
28.	طفل	child	/ṭ/, /f/, /l/	CCVC
29.	مفتاح	key	/m/, /f/, /ṭ/, /ħ/	CVC-CVC
30.	شرطة	police	/ʃ/, /r/, /ṭ/	CVC-CVC
31.	قطة	cat	/q/, /ṭ/	CVC
32.	أسد	lion	/ʔ/, /s/, /d/	CVC
33.	سماء	sky	/s/, /m/, /ʔ/	CV-CV:
34.	نار	fire	/n/, /r/	CV:C
35.	عين	eye	/ʕ/, /n/	CVC
36.	رأس	head	/r/, /ʔ/, /s/	CVC
37.	بقرة	cow	/b/, /q/, /r/	CVCVCV

Num.	Word (Arabic)	Gloss	Target Consonant(s)	Syllable Structure
38.	ولد	boy	/w/, /l/, /d/	CVCVC
39.	نجم	star	/n/, /dʒ/, /m/	CVC
40.	خروف	sheep	/x/, /r/, /f/	CVCVC
41.	جبل	mountain	/dʒ/, /b/, /l/	CVCVC
42.	زرافة	giraffe	/z/, /r/, /f/	CVCVCV
43.	قلم	pen	/q/, /l/, /m/	CVCVC
44.	عصفور	bird	/ʕ/, /s/, /f/, /r/	CVC-CVC
45.	ورق	paper	/w/, /r/, /q/	CVCVC
46.	ثلج	snow	/θ/, /l/, /dʒ/	CVC
47.	خشب	wood	/x/, /ʃ/, /b/	CVCVC
48.	كعكة	cake	/k/, /ʕ/, /k/	CVCVCV
49.	مطر	rain	/m/, /tˤ/, /r/	CVC
50.	قطار	train	/q/, /tˤ/, /r/	CVCVC
51.	طائرة	airplane	/tˤ/, /ʔ/, /r/	CVVCVCV
52.	قرد	monkey	/q/, /r/, /d/	CVC
53.	ذيل	tail	/ð/, /l/	CVVC
54.	بحر	sea	/b/, /ħ/, /r/	CVC
55.	ظل	shadow	/ðˤ/, /l/	CVC
56.	كنز	treasure	/k/, /n/, /z/	CVC
57.	سرير	bed	/s/, /r/	CVCVC
58.	مروحة	fan	/m/, /r/, /ħ/	CVCVCV
59.	عجلة	wheel	/ʕ/, /dʒ/, /l/	CVCVCV
60.	منزل	house	/m/, /n/, /z/, /l/	CVCVC
61.	صورة	picture	/sˤ/, /r/	CVCVCV
62.	بنك	bank	/b/, /n/, /k/	CVC
63.	شجرة	tree	/ʃ/, /dʒ/, /r/	CVCVCV
64.	مصباح	lamp	/m/, /s/, /b/, /ħ/	CVC-CVC
65.	غيمة	cloud	/ɣ/, /m/	CVVCV
66.	وقت	time	/w/, /q/, /t/	CVC
67.	قفل	lock	/q/, /f/, /l/	CVC
68.	جرس	bell	/dʒ/, /r/, /s/	CVCVC
69.	جيب	pocket	/dʒ/, /b/	CVC
70.	حقيبة	bag	/ħ/, /q/, /b/	CVCVCV
71.	زيت	oil	/z/, /t/	CVVC
72.	لعب	toy	/l/, /ʕ/, /b/	CVC
73.	برج	tower	/b/, /r/, /dʒ/	CVC
74.	مصعد	elevator	/m/, /sˤ/, /ʕ/, /d/	CVCVC
75.	ثوب	dress	/θ/, /w/, /b/	CVC
76.	كوب	cup	/k/, /w/, /b/	CVC
77.	قط	cat	/q/, /tˤ/	CVC

Num.	Word (Arabic)	Gloss	Target Consonant(s)	Syllable Structure
78.	قميص	shirt	/q/, /m/, /ṣ/	CVCVC
79.	مطرقة	hammer	/m/, /ṭ/, /r/, /q/	CVC-CVCV
80.	مصباح	lamp	/m/, /ṣ/, /b/, /ħ/	CVC-CVC
81.	فرشاة	brush	/f/, /r/, /ʃ/	CVCVCV
82.	طبق	plate	/ṭ/, /b/, /q/	CVC
83.	ملعقة	spoon	/m/, /l/, /ʕ/, /q/	CVCVCV
84.	بسكويت	biscuit	/b/, /s/, /k/, /w/, /t/	CVC-CVVC
85.	طماطم	tomato	/ṭ/, /m/, /ṭ/	CVCVCVC
86.	موزة	banana	/m/, /w/, /z/	CVCVC
87.	شمس	sun	/ʃ/, /m/, /s/	CVC
88.	جريدة	newspaper	/ʤ/, /r/, /d/	CVCVCV
89.	حذاء	shoe	/ħ/, /ð/, /ʔ/	CVCV:ʔ
90.	بابا	dad	/b/	CVCV
91.	ماما	mom	/m/	CVCV
92.	فم	mouth	/f/, /m/	CVC
93.	أنف	nose	/ʔ/, /n/, /f/	CVC
94.	رجل	man	/r/, /ʤ/, /l/	CVCVC
95.	امرأة	woman	/ʔ/, /m/, /r/	CVCVCV
96.	ثعلب	fox	/θ/, /ʕ/, /l/, /b/	CVCVC
97.	ضفدع	frog	/ḍ/, /f/, /d/, /ʕ/	CVCVC
98.	سلحفاة	turtle	/s/, /l/, /ħ/, /f/	CVCVCVC
99.	قنفذ	hedgehog	/q/, /n/, /f/, /ð/	CVCVC
100.	دراجة	bicycle	/d/, /r/, /ʤ/	CVCVCV