Phonological delay of segmental sequences in a Greek child’s speech

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ABSTRACT
This paper investigates persistent elements of protracted phonological development (PPD) at ages 5;10 and 6;3 in a monolingual Greek girl’s speech following earlier articulation intervention (3;6) and post-intervention assessment (4;3). The re-assessment data examined here, five months apart, were elicited using the Phonological Assessment for Greek (PAel). Results reveal interesting idiosyncratic patterns in the production of segmental sequences (V.V, CC) in complex syllables and longer words, with a striking imbalance between singletons and sequences, which holds especially true for inconsistency in the acquisition of /i/ across CV, CC, and C.C contexts. Phonological delay surfaces as chronological mismatches, idiosyncratic forms and, most notably, disparity between segmental and structural development.

Introduction

In this paper we examine the protracted (delayed) phonological system of a monolingual Greek girl at ages 5;10 and 6;3, utilizing the Phonological Assessment for Greek (PAel) (Babatsouli, 2019). The tool and data analysis follow a constraints-based nonlinear framework (e.g., Bernhardt & Stemberger, 2017). This child’s accuracy is lower in vocalic and consonantal sequences (V.V, diphthongs, C.C and CC), mostly in complex syllables and longer words, revealing a striking imbalance between singletons produced in short (CV or CVCV) words versus longer words, and protracted development of /i/ with inconsistent realizations across CV, CC, and C.C contexts. This article is structured in five sections: (1) the introduction outlining Greek phonology, its development in children, and a brief overview of the child case; (2) the method; (3) the child’s profile; (4) the discussion, and (5) conclusions. For a comprehensive description of Greek phonology, its acquisition by children, and available assessment batteries, see Babatsouli (2019). Further background may also be found in the Introduction to this special issue.

Greek phonology

The sound system of Modern Greek (el, ISO 639.1, 2018), is the standard variety spoken in Greece, also acquired by our child participant. Greek has an average ranking with regard to how frequent speech sound segments are in the phonemic and phonetic inventories across the world’s languages (see Babatsouli, 2019).
**Prosodic structure**

Greek is a syllable-timed language with a basic trochaic (Sw) foot (Holton et al. 2002). The few monosyllables are function/loan words. Longer words comprise up to five syllables, while compounds may exceed five syllables. Onsets, while optional, can have up to three consonants, but CV is most common. Codas are also optional and more restricted in inventory (see below) (Setatos, 1974). Greek syllable distributions are comprehensively outlined in Setatos (1974) and discussed in Babatsouli (2019). Greek stress falls on either of the last three syllables, being primary, secondary or enclitic. Primary stress is contrastive, e.g., adult surface /miˈaUl/ ‘speech’ vs. /’miXa/ ‘miles’. Enclitic stress is morphosyntactically determined, as in the+noun+possessive pronoun, e.g., to /ˈproso.po.tis/ ‘her face’ (Holton et al., 2002).

**Segmental inventories**

The Greek vowel inventory includes five monophthongs /i, e, v, u, o/ and two diphthongs: /vi, oi/. The offglide may be glided to [j] (Setatos, 1974), while the vowel sequence /v, u/ may optionally be diphthongised in Northwestern Greek dialects, e.g., [ˈfru.ule − fru.ˈle] ‘strawberry’ (Baltazani & Topintzi, 2010).

Table 1 groups consonants in bold and their obligatory allophones in parentheses. The following allophones are productive: /m/ assimilates to [ŋ] before /f v/; /n/ assimilates to [ŋ] before velars /k/, /g/ /x/ /γ/; /s/ is voiced before voiced consonants, e.g., /syu.ˈre/ → [zyu.ˈre]; /n/ and /l/ are palatalized to [ŋ] and [ʎ] respectively before /i/ followed by /v, e, j, o/ or /u/, and before single /i/ or /e/ in some dialects; similarly, /k/, /g/, /x/, /γ/ are palatalized to [č], [ʝ], [c] and [j] respectively before single /i/ or /e/, and before /i/ followed by /v, e, j, o/ or /u/. Voiced plosives are prenasalized /b/ → [mb], /d/ → [nd], /g/ → [ŋg], e.g., [vvoˈkendo] ‘avocado’, subject to dialectal, gender and generational variation (Arvaniti, 2007). The rhotic is a tap [ɾ] (Nicolaidis, 2001), varying as trill or approximant in dialects (Trudgill, 2003).

Singleton onsets include all consonant sounds except [ŋ]. Codas (also optional) are limited to a subset of onset singletons: /f, v, s, z, θ, ð, m, n, l, r, k, x, g, y, j/ word-medially, and /s/ or /n/ word-finally. Loanword codas, as in /tvũks/ ‘tanks’ and /bul.ˈdoz/ ‘bulldozer’, permit more

| Features                      | Consonants                                                                 |
|-------------------------------|---------------------------------------------------------------------------|
| **Manner**                    |                                                                           |
| [+consonantal]                | p b [mb] f v m [ŋ] t d [nd] s [z] n [n] ŋ / t ŋ t s dz k [c] g [ŋg] [ŋ] x [c] y [j] l [k] r |
| [-consonantal]                | j w                                                                       |
| [+lateral]                    | l [k]                                                                     |
| [+nasal]                      | m [n] n [ŋ] ŋ                                                           |
| [-continuant] [-nasal]        | p b t d k [c] g [ŋ]                                                     |
| [+continuant] [+nasal]        | f v s [z] ŋ ŋ x [c] y [j]                                               |
| [+sonorant]                   | ts dz                                                                    |
| [-continuant] [+continuant]   |                                                                           |
| **Place**                     |                                                                           |
| Labial                        | m p b f v w                                                               |
| Coronal [+anterior]           | n t d s z ŋ ŋ t s dz l r                                                 |
| Coronal [-anterior]           | [c] [g] [ŋ] [ŋ] ŋ                                                        |
| Coronal [+grooved]            | s z t s dz                                                               |
| Coronal [-grooved]            | ŋ ŋ (and all coronal stops and sonorants)                                |
| Dorsal                        | [+high]: k [c] g [ŋ] x [c] y [j] *w *                                    |
| **Laryngeal**                 |                                                                           |
| [-voiced]                     | p f t s ŋ t s k [c] x [c]                                                 |
| [+voiced] (obstruents)        | b v d z ŋ t s dz g [ŋ] y [j]                                                |
| [+spread glottis]             | f s ŋ x [c]                                                              |
variation. There are some 65 onset clusters, as well as heterosyllabic clusters; CCs predominate over CCCs (s+ OBSTRUENT+LIQUID), being NASAL+NASAL, s+OBSTRUENT, OBSTRUENT+OBSTRUENT, and OBSTRUENT+SONORANT(LIQUID/NASAL) (Setatos, 1974).

**Greek phonological development**

Greek phonological development is addressed in cross-sectional and single child case studies (Babatsouli, 2017; PAL: Panhellenic Association of Logopedics, 1995). Though no exact criteria are discussed, monophthongs are reported acquired by 4:0 (PAL: Panhellenic Association of Logopedics, 1995). See also Babatsouli (2020) for information on hiatus and diphthong acquisition.

Single-case child studies show acquisition of /θ/, and some clusters (/sC/ and FRIкатIVE +LATERAL) by 4:0 (Babatsouli, 2017; Yavaş & Babatsouli, 2016), but cross-sectional studies (PAL: Panhellenic Association of Logopedics, 1995) report interdental and /s/ as late-acquired between 4:0–4:6, and 5:6–6:0, respectively, with Greek clusters acquired by 6:0 as follows: sp-st-pl-kl-vl-vy-pn-kn-tç-pç (3:6–4:0); st-sk-sc-ps-ks-xt-pr-br-tr-fl-fr-mn-zm-bj-ðj (4:0–4:6); sf-ps-f-xt-sc-ps-ks-xt-pr-br-tr-fl-fr-mn-zm-bj-ðj ; yl-γr-spr-str (5:0–5:6); ðr-ðr (5:6–6:0). Cluster mismatches involve reductions, simplifications, epenthesis, coalescence, and metathesis/migration (Mennen & Okalidou, 2006). Cross-linguistically, cluster reductions in typically developing (TD) English monolinguals, for example, significantly decrease by 2:6, though they are still fairly common at 5:0 and sporadic between 6:0–8:0 (McLeod et al., 2001). Literature on phonological delay is scarce: (1) Babatsouli (2019), describing the speech of one girl aged 4:8 using PAel; (2) a study of seven Cypriot Greek late talkers and controls at 30, 32 and 36 months (Petinou & Okalidou, 2006), documenting word-initial consonant omissions and language-specific constraints. Further data on Greek is not available, but the existing studies support markedness universals during phonological delay. Cross-sectional studies have also examined recently phonological awareness and processing (Geronikou, 2018; Geronikou et al., 2020).

**The case**

This study uses PAel (Babatsouli, 2019) to examine phonological delay in a monolingual Greek girl at 5:10 (T1) and 6:3 (T2), including interactions of singletons and sequences. Phonological delay is indicated by non-age-level phonological simplifications and inconsistency of productions across contexts.

**Method**

**Participant**

“Dorothea” is a monolingual standard Greek speaker living in Greece. She is healthy and enjoys socializing and school. Parental written consent was obtained for the study following the Declaration of Helsinki ethical procedures. She was assessed by the second author at the Clinic of the Department of Speech and Language Therapy of the University of Patras.
An only child of university graduates, Dorothea had no developmental delays as a preschooler except for speech production and possibly some slowness on diadochokinetic (DDK) tasks. First words emerged around 2;0, and expressive language by 3;6, but she was unintelligible to strangers and teachers because of simplifications at the segmental and syllable levels, e.g., /fe′.ge.ɾi/ [ɾi. te.li] ‘moon’, /pe′.xi.no/ [ci. si.ni] ‘toys’. Articulation therapy once a week for seven months targeted production and DDK skills, focusing on core vocabulary and clusters. Post-intervention assessment (4;3) showed progress in [+continuant], place of articulation, and some clusters, e.g., /li.mni/ [li.mni] ‘lake’, but circumstances stalled intervention procedures. Between 2019 and 2021, Dorothea attended preschool and kindergarten and, because concerns persisted, her parents requested a second consultation.

**Procedures**

Re-assessment took place at 5;10 (T1) and 6;3 (T2) using PAel (Babatsouli, 2019, [http://www.phonodevelopment.sites.olt.ubc.ca](http://www.phonodevelopment.sites.olt.ubc.ca)) which comprises two word lists, a Screener (50 words) and Extended A&B (51 + 51 = 102 words) lists, plus a 1,001-word narrative (N). Word-list data were elicited using the PAel culture-relevant colour images (one per word) that are freely available in slideshow software from: [http://www.phonodevelopment.sites.olt.ubc.ca](http://www.phonodevelopment.sites.olt.ubc.ca). Sentence cues (cloze technique), and/or phonemic, syllabic cues, included in the slideshow for clinical use to motivate children during the test, were minimally utilized as needed. This battery for nonlinear analysis was preferred for reassessment because of its comprehensive coverage of Greek phonology in terms of phones, consonant clusters, word shapes, stress patterns, and syllable types per word position; for instance, there is a parallel between Setatos (1974) computations of segmental (including allophones) distributions in Greek and those in PAel. For a detailed discussion, see Babatsouli (2019). Dorothea’s running speech was also assessed at T2, as she retold the story in her own words following her mother’s narrative (N) readings. Digital recordings on a laptop placed 50 cm away with a built-in Lenovo Audio Device were configured to 2 channel, 16 bit, 48000 Hz; the data were stored in compressed M4A format. Transcriptions in IPA were performed independently by the authors, both native speakers and trained phoneticians. Minimal inter-rater disagreement (6%) was resolved through consensus in follow-up listening sessions. Supplemental File 1 provides the word list and transcriptions of productions. For examples in the text, we refer to Supplemental File 1 with number-codes as follows: Screener (S), Extended lists A, B, e.g., A3 refers to the third word in Extended A. Supplemental File 2 summarizes the data in the nonlinear analysis scan. Quantitative analysis was computed in spreadsheets.

**Case profile**

Global measures are presented first to show Dorothea’s strengths that contrast with very specific needs regarding consonant clusters, presented in detail for the bulk of the profile. The following measures are included for T1 probes regarding clusters: cluster reductions, Percent Consonants Correct (PCC), Percent Clusters Correct (PCIC), Measure for Cluster Proximity (MCP) (there was less than 10% change at T2).
Global measures for T1 screener

Global measures for T1 Screener data are presented first because the Screener enables a preliminary account of the child’s phonological skills. Screener words comprise 44% (125/281) vowels and 56% (156/281) consonants. Production of monophthongs and diphthongs shows no errors in the Screener.

The predominant consonant mismatch was /l/→[l], though word-initial /v/, /ð/ and word-medial /θ/, /ð/ also showed mismatches in multisyllabic words containing CVC. T1 Screener assessment revealed an overall PCC of 79% (123/156), with singleton consonants PCC of 92% (82/89), a PCC in clusters of 64% (36/56) and for heterosyllabic clusters, 55% (6/11), resulting in a Whole Word Match (WWM) of 50% (25/50). Whole Syllable Match (WSM) varied with syllable type: V = 100% (9/9), CV = 97% (70/72), CVV = 100% (2/2), CCV = 50% (11/22), CCCV = 0% (0/2), VC = 60% (2/3), CVC = 70% (7/10), CCVC = 0% (0/3). The Percentage Clusters Correct (PClC) was 40% (10/25), where 93% (14/15) were cluster reductions, and one Timing Unit Match with substitution in /xt/→[st].

NB: SC (screener), EA (Extended list A), EB (Extended List B), W (weighted)

Global measures at T1 and T2

The section presents global measures comparing the child’s performance at T1 and T2. Starting with vowels, Percentage Vowels Correct (PVC) is 98% at both assessment times, as shown in Table 2. Monophthongs are produced accurately except in hiatus contexts. The diphthong /ei/ is accurate both times targeted. Vowels in hiatus are targeted as follows: 2 /i.e/, 2 /i.o/, 1 /o.e/, 2 /o.i/, 1 /e.e/, and 1 /e.i/ and produced accurately. Hiatus errors occur in /b.e.ˈro.stɛ.tə/ ‘hot air balloon’ (A7), where /b.e/ becomes [o] (T1) and [v. le] (T2), and in /xɛt.tɛ.ˈtɔs/ ‘kite’ (B5), where /ɛt.ɛ/ becomes /ɛ.i/ at T1, but it is adult-like at T2. Table 2 also compares consonant performance at T1 and T2 in terms of PCC, PClC, and WWM values. It is seen that there is, by and large, consistency in the child’s production of consonants at the two assessment periods, though some progress is indicated at T2.

Word structure: general

Mismatches affecting word length and shape occurred in vowel hiatus, V₁V₂, of multisyllabic words. The productions in the examples below indicate syllable reduction through deletion of a vowel in the hiatus (examples 1, 3, 4), consonant epenthesis/metathesis

Table 2. Comparison at T1 and T2.

|       | PCC (%) | PVC (%) | PClC (%) | WWM (%) |
|-------|---------|---------|----------|---------|
|       | SC   | EA   | EB | SC   | EA   | EB | SC   | EA   | EB | SC   | EA   | EB | SC   | EA   | EB |
| T1    | 79   | 75   | 71 | 98   | 97   | 98 | 33   | 42   | 34 | 50   | 33   |   |      |      |    |
| T2    | 83   | 80   | 75 | 99   | 98   | 98 | 41   | 53   | 43 | 56   | 43   | 39 | 58   | 36   | 43 |
| T1 (W)| 75   |      |   | 98   |      |   | 36   |      |   |      |      |   |      |      |    |
| T2 (W)| 79   |      |   | 98   |      |   | 45   |      |   |      |      |   |      |      |    |

NB: SC (screener), EA (extended list A), EB (extended list B), W (weighted)
affecting syllable shape (examples 2, 6), and substitution of a vowel in the hiatus (example 5).

|       | Adult                      | Child                     | Note                      |
|-------|----------------------------|---------------------------|---------------------------|
| (1)   | e.ə.ˈro.ste.to (A7)        | [o.ˈlo.ste.to]            | backing/assimilation      |
| (2)   | [e.ˈle.o.ste.to]           | epenthesis/metathesis     |
| (3)   | [e.ˈlo.ste.to]             | V₂ deletion               |
| (4)   | xerce.əˈtos (B5)           | [xe.ˈte.ˈto]              | V₁ deletion               |
| (5)   | [xe.ˈte.ˈi.ˈtos]           | V₂ raising                |
| (6)   | pro.ˈi (S41)              | epenthesis/metathesis     |
| (7)   | ˈye.ɪ.ˈe.ros (B6)          | [ˈje.ˈye.los]             | off-glide deletion        |
| (8)   | [ˈye.ˈe.los]               | donkey                    |

Similar reductions were observed in diphthongs:

- Syllable shape mismatches occurred overwhelmingly in clusters, especially across syllable boundaries: 100% (4/4) deletions (rather than substitutions) of coda /ɾ/, except for a single adult-like token in [θə.ˈmo.me.ˈtro] ‘thermometer’ (A25) at T2 and onset /x/, e.g., /ɛ.ɾɛ.ɾi.ˈsto/ [fɛ.ˈɡv.i] ‘thank you’ (S2), and substitutions of coda /ɾ/, e.g., /sfi.ˈri.ˈxtrv/ [sfi.ˈli.stv] ‘whistle’ (A44) at T1, though adult-like at T2.
- Two other mismatches involved word-final (WF) /ɔ/ deletion in multisyllabic words or vowel hiatus (e.g., /stru.ˈθo.ˈkɛ.ˈmi.los/ [stʃu.ˈko.ˈmi.li] ‘ostrich’ S50, and #4 above), and lateral migration e.g., /vIˈvli.o/ [li.ˈvi.o] ‘book’ (S24), the latter occurring at both timepoints as the only /v/ mismatch.

**Singleton consonants**

One of the key elements of Dorotha’s phonology was the high match for singleton consonants at T1 (92% PCC). Singleton mismatches occurred for the liquid /ɾ/ across positions, and occasionally for certain fricatives: word-initial (WI) /v/ and /ð/ and word-medial (WM) /θ/. Singleton tap was deleted as onset only once in /fɛ.ˈɡv.ɾi/ [fɛ.ˈɡv.i] (A20), and in most coda occurrences (25), except in the adult-like productions of /θɛ.ˈmo.me.ˈtro/ ‘thermometer’ (A25) and /ɛ.ɾɛ.ˈli.ˈtɔs/ ‘tools’ (S4) at T2/T2N. The only substitution for /ɾ/ with 64 tokens was the lateral [l], although some onset matches are noted at T2: WI /vɪ.ˈvli.ˈdi/ ‘magic wand’ (B14, N); WM /n.ɾo/ ‘water’ (A19); /ɛ.ɾɛ.ɾi.cl/ ‘small hand’ (A31), and by migration, /po.ˈɾi/ [po.ˈɾi] ‘morning’ (S41, N), alongside two coda matches in /θɛ.ˈmo.me.ˈtro/ (A25) and /ɛ.ɾɛ.ˈli.ˈtɔs/ (S4). Migration also affected WF fricatives /v/ and /ð/, with liquid [l] moving into WI onset from a consonant sequence: /vI.ˈvli.o/ [li.ˈvi.o] (3 tokens) ‘book’ (S24); /θɛ.ˈfi.ˈni/ [le.ˈfi.ˈni] ‘dolphin’ (2 tokens) (A26). (See below under Consonant Sequences.) Lastly, WM /θ/ surfaced as [f] twice in /stru.ˈθo.ˈkɛ.ˈmi.los/ [stʃu.ˈko.ˈmi.li] ‘ostrich’ (S50), showing possible assimilation to the labial /m/ (T1, T2; not in N). Two additional singleton mismatches affected word shapes (see above /stru.ˈθo.ˈkɛ.ˈmi.los/ ‘ostrich’ and /xɛ.ˈtə.ˈtɔs/ ‘kite’ with WF /ɔ/ deletion).

**Consonant sequences**

The major constraint in Dorotha’s system concerned consonant sequences. We first present global measures and then discuss the various clusters in detail.
Cluster measures at T1

There were 39 WI clusters and 22 WM clusters in all three probes: Screener, Extended A and B (See Tables 2 and 3.)

Though not balanced for phoneme type and frequency, a comparison of PCC in singletons and sequences is presented. While the child’s singleton PCC was 92%, her

| Sequence       | Manner | Place | Voicing | Cs | Word-initial | Note | Word-medial | Note |
|----------------|--------|-------|---------|----|--------------|------|-------------|------|
| Obstruent      | Stop+Stop | LC    | [-][+]  | pt | 0/1          | c    | A           |
| Obstruent      | Stop+Fric | LC    | [-][+]  | ps | 1/1          |
|                |        | LD    | [-][+]  | ps | 1/1          |
|                |        | CD    | [-][+]  | tç | 0/1          | c    | C           |
|                |        | LD    | [+][+]  | bj | 1/1          |
|                |        | DC    | [-][+]  | kt | 0/1          | st  |
|                | Fric+Fric | LC    | [-][+]  | fθ | 1/1          |
|                |        | LC    | [+][+]  | vθ | 0/1          | v   |
|                |        | LD    | [+][+]  | ψψ | 1/1          |
|                |        | LD    | [+][+]  | vj | 1/1          |
|                |        | CL    | [-][+]  | sf | 1/1          |
|                |        | CL    | [+][+]  | zv | 0.5/1        |
|                |        | CD    | [-][+]  | dʒ | 1/1          |
|                |        | CD    | [-][+]  | sx | 1/1          |
|                |        | CD    | [-][+]  | ɔs | 1/1          |
|                |        | DC    | [-][+]  | xθ | 0/1          | st  |
|                |        | DC    | [+][+]  | yθ | 0/1          | v   |
|                |        | LC    | [-][+]  | sp | 1/1          |
|                |        | CC    | [-][+]  | st | 1/1          |
|                |        | CD    | [-][+]  | sk | 1/1          |
|                |        | LC    | [-][+]  | ft | 0/1          | f   |
|                |        | DC    | [-][+]  | xt | 0/1          | st  | 0/1          |
|                |        | DC    | [+][+]  | yθ | 0/1          |
|                | Obstruent | Stop+Nas | [-][+]  | pn | 0/1          | p   |
|                | Obstruent | Stop+Lat | [-][+]  | pl | 1/1          |
|                | Obstruent | Stop+Tap | [-][+]  | pr | 0/1          | p   |
|                | Obstruent | Stop+Tap | [+][+]  | br | 0/1          | b   |
|                | Obstruent | Stop+Tap | [+][+]  | tr | 0/1          | t   |
|                | Obstruent | Stop+Tap | [+][+]  | dr | 0/1          | d   |
|                | Obstruent | Stop+Tap | [-][+]  | kr | 0/1          | c   | P            |
|                | Obstruent | Stop+Tap | [+][+]  | gr | 0/1          | g   |
|                | Obstruent | Stop+Tap | [-][+]  | zm | 1/1          |
|                | Obstruent | Stop+Tap | [-][+]  | xn | 0/1          | x   |
|                | Obstruent | Stop+Tap | [+][+]  | vθ | 0/1          | v   |
|                | Obstruent | Stop+Tap | [+][+]  | yθ | 0/1          | θ   |
|                | Obstruent | Stop+Tap | [+][+]  | δθ | 0/1          |
|                | Obstruent | Stop+Tap | [-][+]  | xr | 0/1          | x   |
|                | Obstruent | Stop+Tap | [+][+]  | γr | 0/1          | γ   |
|                | Obstruent | Stop+Tap | [+][+]  | mn | 1/1          |
|                | Son-Son | Nas+Mas | [-][+]  | mn | 1/1          |
|                |         |         |         |    |              |      |             |
| Total Full Match |       |       |         |    | 17.5/39 (45%) |      | 7/22 (32%)  |
| Timing Unit Match |     |       |         |    | 21.5/39 (55%) |      | 9/22 (41%)  |

Fric = fricative; Nas = nasal; Lat = Lateral; L = Labial, C = Coronal, D = Dorsal. A = assimilation, AP = allophonic palatalization rule, V = voice, M = metathesis, C = coalescence, L = labialization. Mism = mismatch. Grey shading with bold highlights matches.
PCC in clusters (individual consonants in clusters) was 64% (67% WI, 59% WM) and her heterosyllabic clusters PCC was 55%, preliminary evidence of difficulty in consonant sequences. On similar grounds, all four measures indicate better performance word-initially than word-medially (Table 4), though the numbers are too small to make conclusive generalizations. This holds for WI OBSTRUENT+OBSTRUENT /slC/, STOP +FRICATIVE, STOP+STOP, and FRICATIVE+FRICATIVE /ðθ/, /fç/) and WI clusters involving SONORANT (NASAL+NASAL, STOP+LATERAL). An exception is WM FRICATIVE+NASAL /zm/. Among all, NASAL+NASAL, /s/+STOP, and FRICATIVE+FRICATIVE do well irrespective of position. Reductions to the obstruent occur overwhelmingly in OBSTRUENT+SONORANT clusters: all /θ/ and /n/ tokens, but also /l/ in FRICATIVE+/l/, and once word-medially in STOP +/l/. Less consistent reductions occur for OBSTRUENT+OBSTRUENT in single tokens of /pt/, /tcp/, /vð/, /ʔð/.

**Cluster matches and mismatches**

Dorothea’s cluster productions on the Screener and Extended (T1, T2) are compared cumulatively here, beginning with the Screener for initial assessment. In the Screener, she produced 16/27 clusters (59%) as singletons (7/13 word-initially; 9/14 word-medially), i.e. Timing Unit Match for clusters was 41%, a low match level for a five-year-old and indicative of her protracted phonology. As noted above for WI and WM positions across probes, Screener clusters containing /s/, NASAL+NASAL, OBSTRUENT+OBSTRUENT /pcç/, fçç/, /ðj/ and WI STOP+LATERAL had the highest match levels.

The Timing Unit Matches across probes involve all combinations of manner classes, OBSTRUENT and SONORANT, and are produced either adult-like or with substitutions. Adult-like outputs in 100% of tokens is documented in: (1) NASAL sequences: /mn/, /mpl/, /zm/, though /zm/ is devoiced at T2; (2) OBSTRUENT-only sequences: /pcç/, /bjj/, /fθ/, fcç/, /zyl/, /θj/, /dj/, /sp/, /stf/, /sk/, /sf/, /scç/, /sx/, /ps/; and (3) OBSTRUENT+LATERAL: /pl/, /bl/, and WI /kd/, /fl/. Less consistent Timing Unit Matches containing sonorants are FRICATIVE+NASAL (1/2), STOP+LATERAL (3/4) and FRICATIVE +LATERAL (1/4), while those with obstruents are STOP+STOP (1/2 tokens), STOP+FRICATIVE (5/6), FRICATIVE+STOP (6/7), and FRICATIVE+FRICATIVE (12/14) (examples are provided in the mismatches below). Substitutions target the first member, C₁, in STOP+FRICATIVE, /ks/→/ts/ (S47) and FRICATIVE+STOP, /xt/→[ft, st, kt] in ‘/ni.xtu/’night’ (S19), /o.’xto/’eight’ (A9), /sfi.’rix.trt/’whistle'
(A44), /'xte.ni/ 'comb' (A49), and both members in FRICATIVE+FRICATIVE, which is produced as FRICATIVE+STOP, /xθ/→[st] in /xðes/ 'yesterday' (B51). Largely, strengths in cluster production reflect accuracy of individual segment types as indicated in the global measures (see Table 4).

The Timing Unit Mismatches (including for three-element clusters) showed various patterns: i) deletion of one element (e.g., 1 out of 3 /kl/→[k] /'ku.kle/ 'doll' (S13); ii) deletion and substitution (e.g., 1 out of 4 /γð/→[v] in /'γðe.ni/ 'he scratches' (S49); iii) deletion plus assimilation or metathesis/migration (e.g., 1 out of 3 /pt/→[c] in /pti.'cio/ 'certificate' (B15); iv) coalescence, 3 out of 3 /tç/→[ç] in /'tçe/ 'ears' (S1), or v) deletion plus influence from allophonic palatalization, 1 out of 3 /kr/→[c] in /'kre.b/ 'meat' (B27). It is noted that consonant mismatches in cluster contexts differ than as singletons, e.g., cluster /γ/ becomes [v] in /γð/ /γi/ /γz/, rather than mostly [j] as singleton; another common mismatch pattern is seen in the allophonic palatalization patterns of /pt/→[c], /tc/→[c] and /kr/→[c], just discussed. Reductions are evidenced overwhelmingly in OBSTRUENT+SONORANT and less in OBSTRUENT+OBSTRUENT, but also in heterosyllabic SONORANT+SONORANT.

OBSTRUENT+OBSTRUENT reductions look similar with no reliable response to sonority effects; they primarily involve [+continuant] members reducing to targeted C1 or C2, /vð/→[v] in /'avn.ði/ 'magic wand' (B14), /zv/→[v] in /'zvun.ɾ/ 'spinning top' (A47), or to a substitution, /γð/→[v] in /'γðe.ni/ 'he scratches' (S49), but the output is consistently [Labial, +continuant]. This also holds for heterosyllabic /f.x/→[f] in /ef.xv.ɾi.'sto/ 'thank you' (S2). Exceptions are palatal productions instigated by the Greek allophonic palatalization rule, as in the substituted /ftp/→[ç] of /ftpı.no.po.ro/ 'autumn' (B41); coalesced /tc/→[c] in /'tçe/ 'ears' (S1), /bjiang/→[j] in /'kvb.ɾe/ ‘caterpillar’ (B2), palatal migration, /pti/→[ç], in /pti.'cio/ 'certificate' (B15), and nasal migration, /ðj/→[n], in /pe.'xni.ʤ/ 'toys' (B1). On the contrary, OBSTRUENT+SONORANT reduces to C1, as per sonority universals (Yaşav & Babatsouli, 2016). The retained C1 is overwhelmingly adult-like, whether C2 is NASAL: /pn/→[p] (A51), /xṇ/→[x] (B40), or LIQUID: WM /kl/→[k] (S13), WI OBSTRUENT+/ʧ/ (A4). Two exceptions involve reductions to C2 and vowel contiguity in /xₙ/→[n] of /xₙu.ðu/ 'fluff' (B40) and /γl/→[l] of /γlo.ɾi/ 'tongue' (S40). Variation in C1 production is also documented as: i) C1 substitution, /xṇ/→[s], in /pe.'xni.ʤu/ 'toys' B1 and devoicing, /zmn/→[sm], ii) Greek allophonic palatalization, /xṇ/→[ç], in /pe.'xni.ʤu/ 'toys' (B1), /kr/→[ç], in /'kre.ɾ/ 'meat' (B27), /γɾ/→[j] in /'ti.γɾis/ 'tiger' (S10), or iii) assimilation/migration of [Labial], /γɾ/→[v], in /zo.ɾe.ɾe/ 'drawing' (A29) or of [Coronal] in the word, /γɾ/→[ɾ] in /'ti.γɾis/ 'tiger' (S10). Notably, cluster /x/ is commonly substituted, though singleton /x/ is acquired. As the case of /Ca/, heterosyllabic sequences with /ɾ/, reduce to OBSTRUENT, /ɾ.ɾ/→[t], in /xəɾ.ɾe.ɾo/ 'kite' (B5), /ɾ.k/→[k], in /'pr.ɾu.ɾi/ 'park' (S6), /ɾ.ɾ/→[ɾ] in /'ɾe.ɾu.ɾe/ 'tools' (S4), /ɾ.j/→[j] in /'ɾe.ɾu.ɾe/ 'cucumbers' (A3), or NASAL C2, /ɾ.m/→[m], in /θe.ɾ.ɾu.ɾe/ 'thermometer' (A25) and /ɾ.n/→[n] in /'γðe.ni/ 'he scratches' (S49). Finally, deletion of /ɾ/ is documented in OBSTRUENT+OBSTRUENT+SONORANT sequences, /str/→[st], in /'ksi.ɾe.ɾ/ 'sharpeners' (S47) and /spr/→[sp] in /'v.spros/ 'white' (A1). Again, weaknesses in cluster production reflect lack of mastery of segment types, in this case, /ɾ/.

Production variability at T1, T2 and T2N

Comparing the child’s productions across assessment times, we see that they were not variable, overall. Nevertheless, some inconsistency across different repetitions at T1, T2 and T2 (N) is noted. Nine (9) of the words targeted in PAel across probes are produced
differently on one occasion only, such as at T1: /ˈkυ.κλε/ [ˈkυ.κλε] ‘doll’ (S13), /κρ.ˈpός/ [κρ.ˈpός] ‘smoke’ (A16), /ˈκέββε/ [ˈκέββε] ‘caterpillar’ (B2), /dζε.ˈζί.κί/ [dζε.ˈζί.κί] ‘tzatziki’ (B11), /ˈκέ.βε.ς/ [ˈκέ.βε.ς] ‘meat’ (B27), at T2: /ˈκό.ɾ/ [ˈκό.ɾ] ‘rain’ (A37), /sɹ.iɾx.ɾə/ [sɹ.iɾx.ɾə] ‘whistle’ (A44), /ˈκέ.ɾ/ [ˈκέ.ɾ] ‘comb’ (A49), and at T2 (N) /ɾv.ˈdι/ [ɾv.ˈdι] ‘magic wand’ (B14). Eleven (11) more words demonstrated significantly more variability with differing productions across assessment times. Most notable are: /n.ιx.ɾt/ → T1 [ˈnιςτη] → T2 [ˈnιςτη] → T2 (N) [ˈνιςτη] ‘night’ (S19), /tι.ɾί.ɾ/ → T1 [tι.θίς] → T2 [tι.ɾί.ɾ] → T2 (N) [ˈtʰjις] ‘tiger’ (S10), /ˈɾό.ɾέ.ɾι.ɾ/ → T1 [ˈɾό.ɾέ.ɾι.ɾ] → T2 [ˈɾό.ɾέ.ɾι.ɾ] → T2 (N) [ˈɾό.ɾέ.ɾι.ɾ] ‘he scratches’ (S49), /stɾu.ɾό.ˈκε.μί.λο.ς/ → T1 [stɾuˈɾo.ˈκε.μί.λο.ς] → T2 [stɾuˈɾo.ˈκε.μί.λο.ς] ‘ostrich’ (S50), /r.ε.ˈɾo.ɾet.ɾ/ → T1 [oˈɾo.ɾet.ɾ] → T2 [e.ɾε.ɾo.ɾet.ɾ] ‘hot air balloon’ (A7), and /ˈɾυ.ɾυ.ɾ/ → T1 [ˈɾυ.ɾυ.ɾ] ‘donkey’ (B6). Others were: /ɾι.ɾi.ɾ/ → T1 [ɾι.ɾi.ɾ] → T2 [ɾι.ɾi.ɾ] ‘kite’ (B5), /zo.ɾι.ɾ/ → T1 [zoˈɾι.ɾ] → T2 [zoˈɾι.ɾ] ‘drawing’ (A29), /ɾε.ˈɾι.ɾ/ → T1 [ɾε.ˈɾι.ɾ] → T2 [ɾε.ˈɾι.ɾ] ‘toys’ (B1), /sθε.ɾ/ → T1 [sθε.ɾ] ‘yesterday’ (B51). Such inconsistencies, though not across the board in all targeted words, are evidence in support of phonological delay.

**Discussion**

PAEL (Babatsouli, 2019) was used to facilitate fine-grained assessment of a monolingual Greek girl’s phonology at 5;10 and 6;3, who had received articulation therapy between 3;6–4;1 but continues to show delay. The non-linear analysis of the nature and degree of her persisting phonological difficulties draws attention to needs not observed during previous initial and post-intervention assessments.

Dorothea’s productions were characterized by output patterns that are common for children cross-linguistically, including deletions, substitutions (e.g., /ɾ/→[ɾ]), language-specificity (e.g., /ɾ/→[ɾ]), prototypical processes (fronting/stopping, regressive assimilations), coalescence, and migration (e.g., Bernhardt & Stemberger, 1998; PAL: Panhellenic Association of Logopedics, 1995; Petinou & Okalidou, 2006). Her skill in features also attests to universals, whereby [Dorsal, +back] and [Rhotic] are highly marked, as also evidenced in cluster reductions (more below). The data re-validate constraints leading to simplifications and chronological mismatches at a level above the segment that do attest to phonological delay.

Dorothea had no difficulty producing stress, nor most singletons in CV and CVCV, except for /ɾ/, and the rhotic is late cross-linguistically (McLeod et al., 2001). Though [ɾ] substituted for her /ɾ/ (a common pattern) in CV, she did produce few tokens intervocally, e.g., /ɾo.ɾ/ [ɾo.ɾ] ‘morning’ (S41). However, /ɾ/ was overwhelmingly deleted (not substituted) in CCs and codas, suggesting delay at T2, since /ɾ/ is typically mastered between 5;6–6;0 (PAL: Panhellenic Association of Logopedics, 1995).

Remaining singleton mismatches were affected by structural complexity. Errors were documented in vowel hiatus and diphthongs, in consonant sequences, codas, and multisyllables. hiatus simplified in unstressed contexts and multisyllables, e.g., elision in /v.ε.ɾo.ɾ/ [ɾ] ‘hot air balloon’ (A7) and /V2/→[ɾ] in /ɾi.ɾt.e.ɾ/ ‘kite’ (B5). The literature, although limited, reports some parallels. Petinou and Okalidou (2006) mentions unstressed syllable reduction in late Cypriot Greek talkers. Babatsouli (2019) reports elision in the
anteprepenultimate unstressed syllable of /t.e.’ro.sta.to/ ‘hot air balloon’ (A7), produced as [ɛ.’lo.sta.to], in phonological delay at 4;8. Dorothea’s data at an older age, though based on small numbers, suggest additional constraints: stressed diphthongs are monophthongised (e.g., /’ga.ð.es/ [’ga.ðulos] ‘donkey’, B6), and metathesis resolves hiatus in disyllables /pro. ʼi/→[po. ’ri] ‘morning’ (S41) (e.g., Babatsouli, 2020), similar to /pro. ʼi/→[po.’lo.i] by the child in Babatsouli (2019).

Further interactions were observed for consonant targets, syllable shape and word length, e.g., WF /s/ deletion, WM coda and onset reductions, and substitutions for singletons other than /r/ in multisyllables. Interactions involving medial codas have been reported for TD children and those with phonological delay (Babatsouli, 2019), and were also observed in Dorothea’s VC, CVC for rhotic and other consonants (e.g., heterosyllabic /s/ substitution in /sfi.’ri.x.tre/ [sfi’liste] ‘whistle’ (A44). An earlier pattern, singleton /θ/→[/θ], was documented in /stru.θo.’kvi.mi.los/ ‘ostrich’ (S50), the most complex PAel word for length (5σ) and syllable complexity (CCC/coda). This pattern systematically occurred in multisyllabic words (>3σ): 3/4 Screener complex multisyllables, all 7 Extended A targets, and all 3 Extended B targets. Word length also affected /zm/ ([z] devoiced in trisyllabic /’fr.de. zm/ ‘ghost’ (A21) at T2, though singleton /z/ and /zm/ members were produced), and other fricative /[-cont] clusters, i.e. /xt/→[/ft, st] and accurate /sC/. Similar effects have been reported for English and French in multisyllables (Mason et al., 2015). Certain words appeared idiosyncratic (e.g., S24, S47), since singletons /v/, /s/, /k/ and /s/-sequences were mastered. This is further supported by Babatsouli (2019) for voice mismatches, /’fr.dez.me/ [’fr.dez] ‘ghost’ (A21) and /tsu.’li.θr/ [zu.vi.θr] ‘slide’ (B9), and coda reductions in complex and multisyllabic complex words, e.g., /eﬁ.xe.ri.’sto/ [xe.θe.2i.’sto] ‘thank you’ (S2), /dcl.’fi. ni/ [de.θi.fin] ‘dolphin’ (A26). A comparison of mismatches across T1, T2, and T2N shows that most T2N mismatches are different from those at T1 and T2 (in 8 targeted word types), while there are more common substitutions between T2N and T2 (in 7 targeted word types) than between T2N and T1 (in 5 targeted word types). Lastly, production variability across assessments times, at T1, T2 and T2N, as shown above, further supports Dorothea’s delay in phonological skill.

Consonant sequences were her greatest challenge, particularly with the rhotic. Dorothea’s data pattern well overall with productions in Babatsouli (2019) at 4;8, albeit more advanced, and including reductions to sonorant or C1, prototypical processes, and allophones. Her clusters showed universal patterns relative to sonority, place and manner patterns of reduction and substitution (Bernhardt & Stemberger, 1998), plus known ‘stages’; she did not, nevertheless, show full cluster deletion or vowel epenthesis which appear earlier in acquisition (Babatsouli & Sotiropoulos, 2018). Both frequent cross-linguistic patterns were observed, i.e. earlier acquisition of stop+/l/ than fricative+/l/ (McLeod et al., 2001), and language-specificity, like earlier mastery of /sCs/ in Greek (Yavaş & Babatsouli, 2016) and lexically instigated vowel prothesis in /xø’es/ [’xø’es] ‘yesterday’ (B51), since targeted /’xø’es/-/e’xø’es/ are synonyms. Language-specific substitutions are reported for Cypriot Greek late talkers (Petinou & Okalidou, 2006).

While several of Dorothea’s clusters were mastered, comparing the available mismatches with norms (see introduction), indicates delay in her still-developing clusters, including C +Rhotic: /pr, br, tr, fr/ (4;0–4;6), /dr, vr/ (4;6–5;0), /yɾ, spr, str/ (5;0–5;6), /θɾ-ðɾ/ (5;6–6;0). Though her good /SC/ performance accords with early /s/-sequences acquisition in Greek (Yavaş & Babatsouli, 2016), her /ks/ mismatches do not. Her /zm/ devoicing also indicates
her struggles with laryngeal distinctions (norms report mastery by 3;0, Mennen & Okalidou, 2006). Timing Unit Mismatches reducing to C2 instead of to C1 or substitutions, are exceptional in her fricative+nasal /xn/ → [n] in /ˈfɪtʃə.xnɪ/ ‘she makes’ (B48) and fricative + lateral /yl/ → [l] in /ˈylə.ʃt/ ‘tongue’ (S40). The obstruent+obstruent reduction to [Labial] has been reported before for Valley-Zapotec TD children (Stemberger & Chávez-Peón, 2020). It is notable that same-class combinations, obstruent+obstruent, sonorant + sonorant, are mostly output as clusters, but combining obstruent+sonorant is more challenging. Conclusively, the extent of cluster reductions expected to be sporadic at 6;0 (McLeod et al., 2001), is further indication of Dorothea’s protracted phonology.

More variation in cluster productions is reported by Stemberger and Bernhardt (2018) for children with PPD than TD children. Dorothea’s obstruent+sonorant mismatches reveal such variability. Her /Cl/ and /Cn/ are special in that, while cluster members are mastered as singletons, reductions show universal preference for C1- obstruent, /xn/ → [x, s, ç], /yl/ → [y], but also occasionally retain C2- sonorant, /xn/ → [n], /yl/ → [l]. Additionally, while acquired as singleton, /x/ is mostly substituted in /xn/. By comparison, because non-acquired singleton /r/ is always substituted by [l], her /Cr/ reduces to C1, as expected, but /t/ is never substituted by [l] in /Cr/, as reported for a younger TD child (Babatsouli, 2021), and despite the fact that Dorothea produces stop+lateral and /fl/. This is idiosyncratic and indicates a misalignment between realizations across singleton and cluster contexts. Thus, her phonological delay is influenced by structural constraints imposed by segmental sequences on the syllable and word levels, negatively impacting timely acquisition. This finding is significant because, though clinical approaches to intervention commonly focus on speech sounds (Baker et al., 2018), a non-linear approach to intervention accounting for higher prosodic units (Baker & Bernhardt, 2004) is not only justified, but also mandated.

**Proposed intervention plan**

A non-linear constraints-based approach is advisable for continuing intervention that targets structures, segments and features (see Suplemental File 2 – Scan; page 1 goals). Baker and Bernhardt (2004) analyzed the data of a child with a phonological impairment who had already attended intervention and report on goals achieved by adopting a non-linear approach to intervention. System intrinsic support seems to be efficacious to treatment. The literature also indicates that speech therapy intervention is most effective when it is intensive and is provided for at least a few weeks (Allen, 2013), including the case of intervention based on the principles of nonlinear phonology (Lundebohr Hammarström et al., 2019). On this basis, it is suggested that the client attends speech therapy sessions lasting at least 30 minutes with a frequency of two sessions per week for a period of eight weeks. It is expected that if a re-assessment is conducted upon such an intervention, significant progress will be observed.

Treatment needs (Table 5) (not ordered goals) for Dorothea are:

**Segmental**

(i) Vowels: unstressed /ei/; hiatus /e,e/ in multisyllabic words;
Table 5. Proposed intervention plan (see scan page 1).

| Word Structure (pp. 3–4) | Positional, sequences | Features, Segments: (pp. 5, 7–9) |
|--------------------------|------------------------|----------------------------------|
| Goals for 1st treatment block with numbered order | Strong segments to use: (p. 5) All in CV except /t/, /v/, /d/; in complex α, and /θ/ in 5–σ word, medial /t/, /v/, final /d/ in short words | Individual features: (Coronal [-grooved]) [+liquid, rhotic] Existing features to combine into new segment(s): ([+continuant, +voiced]) (Dorsal [+continuant]) |
| Therapy strategies by goal # | TX Strategies: Moving from Liquid [+lateral] to Liquid [-lateral], /l/ to /l/ | Strong word shapes to use: (p. 3) CV, CCV |
| Length: multisyllables Stress: n/a Syllable shapes CV, CC, CCC, C. CCIV, CCVCCV | Positional: (pp. 5, 6–9) | Multisyllabic words, Complex onsets: C+ tap |
| Syllabic shapes CV, CCC, C. CCIV, CCVCCV, CCV, CCC, CCCC, CCIV | Medial codas, WF /s/: | Strong segments to use: (p. 5) |
| | | All in CV except /t/, /v/, /d/; in complex α, and /θ/ in 5–σ word, medial /t/, /v/, final /d/ in short words |
| | Strong segments to use: (p. 5) | Strong word shapes to use: (p. 3) CV, CCV |
| | Medial /t/, /v/, WF codas: /s/, /l/, /l/: CCs: ps, pc, mn, mp, stop+[l], [+voice, +cont]+[l], scs, level sonority except for interdentals and velars | TX Strategies: Moving from Liquid [+lateral] to Liquid [-lateral], /l/ to /l/ |
| | TX Strategies: Sneaking up on syllable constraints | |
| | - vowel sequences | |
| | - codas segments | |
| | - word-initial clusters with sonorants in C2 | |

(ii) Consonants: /t/; WI /v/; CVC /ð/; WM /x, f, l, ɬ/.

**Word structure needs**

(i) Position/sequence:
- Vowels: Unstressed vocalic sequences in multisyllabic words.
- Fricatives /s/, /z/, /θ/, /ð/, /ʃ/, /θ/, /x/, /y/in long words or complex syllables;
- WF /s/ in multisyllabic words.
- most medial codas;

(ii) CC: C[+cont]+[lateral] vs C[+cont]+[rhotic].

(iii) Morphology: /ks/→[ts] (since /ks/ occurs for future/past tense formation).

A phased approach to intervention would include the following goals:

- Phase 1: singleton /t/, and other singletons in challenging word structures.
- Phase 2: support for segmental sequences, problematic syllable shapes (CVC), and multisyllabic words.
- Phase 3: mostly liquid clusters and WM consonant sequences.

**Conclusion**

This paper has investigated the delayed phonology of a monolingual Greek-speaking girl revealing persisting needs even after intervention. The study brings to light a discrepancy in vowel and consonant production between singletons and segmental sequences in complex, like long words, onsets, and CVCs. Interestingly, though C+[lateral] is acquired, /t/ in C+[rhotic] is deleted rather than substituted by [], as for /v/. Although a single child case study, the results complement the scarce literature on Greek phonological delay, recording under-reported patterns that provide information about the acquisition of phonological complexity in Greek, and lay the groundwork for future cross-
sectional studies. PAel is effective for non-linear phonological analysis, showing constraints that hamper the child’s skill in structural complexity. The present study has illuminated the interplay of underlying hierarchical representations and provides a useful example in Greek for intervention protocols that target higher level representations, beyond simply articulatory skill.

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