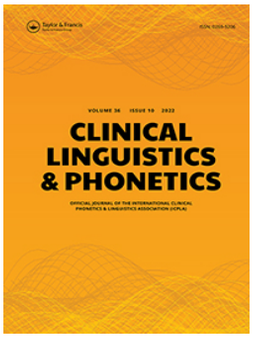

Clinical Linguistics & Phonetics

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/iclp20

Atypical phonological processes in naming errors of children with language impairment

Michal Biran, Gila Tubul-Lavy & Rama Novogrodsky

To cite this article: Michal Biran, Gila Tubul-Lavy & Rama Novogrodsky (2022): Atypical phonological processes in naming errors of children with language impairment, Clinical Linguistics & Phonetics, DOI: 10.1080/02699206.2022.2126331

To link to this article: https://doi.org/10.1080/02699206.2022.2126331

Published online: 10 Oct 2022.

CLINICAL LINGUISTICS & PHONETICS
https://doi.org/10.1080/02699206.2022.2126331

Atypical phonological processes in naming errors of children with language impairment

Michal Biran[a], Gila Tubul-Lavy[b], and Rama Novogrodsky[c]

[a]Department of Communication Disorders, Ariel University, Ariel, Israel; [b]Department of Communication Sciences and Disorders, Ono Academic College, Kiryat Ono, Israel; [c]Department of Communication Sciences and Disorders, University of Haifa, Haifa, Israel

ABSTRACT

The current study explored the characteristics of phonological errors of preschool children with DLD (Developmental Language Disorder), distinguishing between typical versus atypical phonological processes in segmental, syllabic and word levels. The analysis included 87 responses of words with phonological errors from a naming test, produced by 13 preschool children with DLD, aged 4;4–6;3 years. These responses included 166 phonological processes, which were classified into typical and atypical processes at the levels of: segments, syllables, and prosodic words. The findings revealed that 70% of the phonological processes were atypical. Furthermore, ten children produced more atypical processes, and there were more atypical than typical processes in segmental and word levels. It is suggested that some children with DLD represent phonological processes that are similar to those that children with speech and sound disorders produce. Therefore, clinically, the results emphasise the importance of analysing the typical and atypical characteristics of phonological errors as part of language assessment.

ARTICLE HISTORY
Received 5 August 2021
Revised 21 September 2022
Accepted 10 September 2022

KEYWORDS
Naming; phonological processes; DLD; phonological disorder

Introduction

Developmental language disorder

Developmental Language Disorder (DLD, previously termed Specific Language Impairment – SLI[1]), is a primary deficit in language development in the absence of documented neurological damage, hearing deficits, severe environmental deprivation, or mental retardation (Leonard, 2014). The language deficits of children with DLD are described as idiopathic (Bishop, 2014) with heterogeneous profiles. One common profile of DLD is a lexical retrieval difficulty, also termed as word finding difficulty (Dockrell et al., 1998; Friedmann & Novogrodsky, 2011; German & Newman, 2004; McGregor, 1997; Novogrodsky & Kreiser, 2015). Word finding difficulties represent the difficulties of one-quarter of the children with DLD (Messer & Dockrell, 2006). It is evident in structured tasks and spontaneous speech and is documented in both monolingual and bilingual children (Degani et al., 2019). When children with word finding difficulties fail

CONTACT Michal Biran michalbi@ariel.ac.il Department of Communication Disorders, Ariel University, Ramat HaGolan St. 65, Ariel, Israel

The first and the second authors declare an equal contribution.

[1]For an overview of the change see Bishop et al. (2016), Novogrodsky and Kreiser (2019).

to produce a target word, they present various types of responses including semantic errors (e.g. *lemon* for *orange*), gestures, hesitations and descriptions. Phonological errors are also produced, and they include: nonwords (e.g. [gilon] for /vilon/ 'curtain'), formal errors – phonological substitution that creates an existing word (e.g. [milon] 'dictionary' for /vilon/ 'curtain'), and approximations (e.g. [maf . . . ma.] for /maftex/ 'key') (Biran et al., 2018; Faust et al., 1997; McGregor, 1994). The current study explored phonological errors that were produced by preschool children with DLD in a naming task, examining the phonological processes[2] of each phonological error.

Typical acquisition of phonology

Acquisition of phonological knowledge is part of children's language development and it reaches proficiency by the age of 4–5 years (Ingram, 1986). A review study of 27 languages (including Hebrew, the target language of the current study) reported that children acquire all the consonants of their language by the age of 5 (McLeod & Crowe, 2018). Specifically, in Hebrew, most of the segments are acquired at age 2:06-3:00 except / ʁ/, which is acquired by age 4, and sibilant consonants, which can be acquired beyond the age 6 years. The prosodic word level is acquired by age 4, and the syllable structure is acquired by 4:06 (except initial clusters). For example, by age 4, children produce four-syllable words (/melafefon/ 'cucumber'), words with a middle coda (/mitbax/ 'kitchen'), and phonologically complex words (e.g. /sufganija/ 'donut') (Ben-David, 2020). It is thus suggested that before school-age, children acquire most of the phonological schemes of their language (Ben-David, 2020).

Importantly, studies show a relationship between phonological complexity and vocabulary acquisition, such that words that are phonologically simpler are acquired before words that are phonologically complex (e.g. Braginsky et al., 2019; for Hebrew see, Gendler-Shalev et al., 2021). With age and maturation of phonological abilities, children are gradually able to articulate words more accurately (Viterbori et al., 2018).

Two main theories explain the gap between children's production of target words in their language and the way these words are produced by adults (Grunwell, 1982; Ingram, 1976, 1989). According to the *Natural Phonology Theory* (Stampe, 1969), three main phonological processes characterise typical phonological development: substitutions, syllable simplifications and assimilations[3] In *substitution* processes, one consonant is replaced by another (for example, the process of stopping – a replacement of a continuant consonant with a stop consonant: [bilon] for /vilon/ 'curtain'). *Syllable simplification* includes reduplication of a syllable or a phoneme (e.g. [tata] for /savta/ 'grandmother'), omission of an unstressed syllable[4] (e.g. [nana] for /banana/ 'banana' or [saim] for /mixnasaim/ 'pants') or of final consonant (e.g. [oze] for /ozen/ 'ear'), and simplifying of clusters (e.g. [lida] for /glida/ 'ice cream'). Finally, in *assimilation*

[2]In this study, we use the term "error" when referring to an erroneous word response in the naming task (i.e. a phonological error/paraphasia), and the term "process" when referring to the phonological errors (substitutions, deletions, etc.) within the erroneous word response. Because of the low number of errors produced by each of the participants in the study, we cannot make a claim for the existence of a specific phonological process for each individual child.

[3]A phonological process is a mental operation that applies to a class of sounds presenting a specific difficulty of the speech capacity (Donegan & Stampe, 1979)..

[4]Because words are acquired from the last and stressed syllables of the word to the first unstressed ones, most omissions are of the unstressed syllables or consonants of these syllables (Grunwell, 1985).

processes, a phoneme becomes similar to another sound in the word (e.g. [tatan] for /katan/ 'little') (Ben-David, 2018). These three phonological processes represent relationships between parts of the produced word and decrease with age towards the correct form of the target word. In contrast to the Natural Phonology Theory, the *Nonlinear Phonology Theory* describes the phonological units in a fixed hierarchical system: a prosodic tier (prosodic words and syllables) and a segmental tier (segments), suggesting that these units interact with each other (Bernhardt & Stoel-Gammon, 1994). According to this theory, different phonemes are acquired at different ages and they interact with prosodic tiers. For example, a 3-year-old child produces /m/ in the coda of the word /xalom/ ('dream') but omits it in the onset producing [ita] for the word /mita/ ('bed') due to the preference to sound sonorants in the coda. Similar to the Natural Phonology Theory, with age children acquire more phonemes and more complex tiers and as a result produce more complex words.

Phonological disorders

Speech Sound Disorders (SSD) are difficulties in producing speech. SSD interferes with communication, and includes phonetic disorders relating to motor difficulties, phonological disorders relating to cognitive-phonological difficulties, or both (Diagnostic and Statistical Manual of Mental Disorders – DSM-5, American Psychiatric Association, 2013). Based on questionnaires completed by speech and language therapists in different countries, 40%-80% of the children referred to therapy are children with SSD (Baker & McLeod, 2004; Joffe & Pring, 2008; Pascoe et al., 2010; Tubul-Lavy et al., 2018). Importantly, among children with SSD, errors characterised by non-developmental processes (equivalent to the term 'atypical processes' used in the current study) predict long-term problems in phonological awareness, reading accuracy, spelling, and reading comprehension (e.g. Dodd et al., 2018; Leitão & Fletcher, 2004). Dodd et al. (2018) tested 93 children at age 4 and 7 longitudinally, using standardised assessment. They categorised the phonological errors as 'delayed' – meaning error patterns that are typical of younger children, versus 'atypical' – meaning errors that are not produced by children with typical development (e.g. word initial consonant deletion). Their findings showed that children who had delayed errors tended to show typical development at the age of 7 compared with children who still showed atypical errors.

It is suggested that children with SSD experience difficulties in literacy, with increased risk when there is comorbidity with DLD (Anthony et al., 2011; Lewis et al., 2000; Nathan et al., 2004). While SSD is restricted to speech production, DLD is a wider disorder, which includes difficulties in language production, comprehension, or both. The term *developmental* in the DLD diagnosis highlights its influence on language acquisition during childhood and the term *disorder* emphasises that it is a lifelong impairment that affects academic and social functioning (Bishop et al., 2016; Novogrodsky & Kreiser, 2019).

Atypical phonological processes in SSD and DLD

Different tasks aim to detect phonological disorders. These include spontaneous data, single word production and nonword repetition (Anjarningsih & Puryanti, 2022; McLeod

& Crowe, 2018; Sutherland & Gillon, 2005). For example, children with phonological disorders, aged 3–6 years, were less accurate in a nonword repetition task compared with typically-developing age-matched controls, but both groups repeated low-frequency sequences less accurately than high-frequency sequences. It is suggested that phonological disorders are associated with difficulties in building representations in the primary sensory and motor domains (Munson et al., 2005). Dodd et al. (2018) highlighted the need to distinguish between age-appropriate errors, delayed developmental errors and atypical errors. This was shown in a study that tested Brazilian-Portuguese-speaking children aged 3:0-8:11 years with SSD. The children with SSD showed both typical and atypical phonological processes in their errors (e.g. fronting and backing of plosive sounds. Ceron et al., 2017). Hence, there is evidence that children with SSD produce distinctly different error types (Ceron et al., 2017; Dodd et al., 2018; Leitão & Fletcher, 2004).

While a phonological disorder is the most noticeable difficultly of children with SSD, it also appears among children with DLD. Both populations show a gap compared with typically aged-matched controls, in SSD – in speech scores and error types, and in DLD – in language scores (in comprehension, production or both). However, there is an overlap in the phonological difficulties in SSD and DLD. A meta-analysis study of children with DLD showed that they have significantly more errors in nonword repetition tasks compared with control groups (Estes et al., 2007). Furthermore, a longitudinal study of children with DLD showed impaired nonword repetition skills (Weismer et al., 2000). In another study, Italian-speaking children with DLD (mean age 5:1 years), showed severe difficulties with representing complex syllabic structures, suggesting phonological impairment rather than simply slow phonological development (Orsolini et al., 2001). Finally, late-talkers who have a small productive vocabulary show simpler phonological productions compared to age-matched children with typical lexical development (Gendler-Shalev & Novogrodsky, in preparation; Rescorla, 2013; Stoel-Gammon, 2011). Edwards et al. (2011) suggested that phonology develops together with the lexicon and that research needs to explore both lexical and phonological acquisition and the interactions between them. The current study followed this idea and the ones of Leitão and Fletcher (2004), who emphasised the importance of understanding the atypical processes in children's production to clinical assessment and treatment.

Purpose of the current study

The current study explored the phonological errors of children with DLD without a primary diagnosis of SSD in a picture naming task, focusing on the atypical phonological processes of their productions. We explored whether there are more atypical phonological processes than typical phonological processes: (1) at the individual child level, (2) at the group level, considering the three phonological levels: segmental, syllabic and prosodic word. We predicted that there would be significantly more atypical processes compared with typical ones – both at the individual child level and at the three phonological levels.

Note that any typical phonological process is typical in its features, but atypical in terms of chronological age, as all children in the current study were older than 4 years, the age in which Hebrew-speaking children are proficient in their phonological

knowledge, in all three levels. The errors were compared to norms known for Hebrew-speaking children (based on a sample of 1113 Hebrew-speaking children ages 2;02–6;06. Ben-David, 2015).

Method

Participants

The participants were 13 children (10 boys and 3 girls) with DLD, aged 4;04–6;03 years (mean age 5;02), all native Hebrew speakers. We included only children with a naming impairment who produced phonological errors. The data was collected and analysed in a previous study by Biran et al. (2018)[5]

Prior to the original study, comprehensive clinical assessment was administered and all the participants met the inclusionary criteria for DLD (Leonard, 2014). Importantly, none of them was diagnosed with childhood apraxia of speech (CAS), and all the children produced all the consonants in the phonemic inventory of Hebrew (except for the sibilant consonants /s/ and /ts/, which were not counted as errors for children who erred consistently in their production, indicating that they had not yet acquired them).

Materials and procedure

The data of the group of children with DLD were collected in a previous study (Biran et al., 2018) in which 16 children with DLD were tested and their errors were analysed for different types of lexical retrieval errors. Among these errors, 18% were phonological errors (significantly more errors than shown in the control group of children with typical language development [1%]). The words with phonological errors were analysed in the current study as described below.

In the original study, a naming test (SHEMESH, Biran & Friedmann, 2004) was administered to the participants. This test includes 100 colour pictures of concrete nouns from different semantic categories. It is used in the clinic and research for assessment of naming deficits in adults with brain damage (Biran & Friedmann, 2005), school age children (Novogrodsky & Kreiser, 2015) and preschool children (Biran et al., 2018). The words in the test are controlled for length (one to four syllables, three to ten phonemes), phonological characteristics of the opening sound of the word (representing the different phonemes in Hebrew), and prosodic characteristics of stress patterns (ultimate and penultimate). The items include both frequent and infrequent words, and both masculine and feminine nouns (with regular and irregular gender morphology), which is an important characteristic of Hebrew (For more details see Biran & Friedmann, 2005).

In the original study, children were tested individually in a quiet room at a child development institute where they were receiving intervention. The instructions for the children were: 'I will show you pictures of objects. Please tell me, in one word, what you see

[5]Three additional children from Biran et al.'s study were excluded: one who did not produce any phonological errors (this participant, reported as EH in Biran et al., 2018, is presented as a case-study with dominant semantic errors), and two who produced only formal errors, namely, phonological errors that create another existing word.

Formal errors were not included in the current analysis to avoid an overlap between phonological and semantic errors, and the possible effects of word frequency and word familiarity on the analysis..

in the picture'. During the test, children were given general positive feedback regardless of performance. Pictures for naming were presented with no time limit. (See Appendix A for more details about the procedure in Biran et al., 2018, specifically concerning the error type analysis. See Appendix B for the participants' performance in the SHEMESH naming test).

The research was approved by the Ethics Committee of the Child Developmental Unit where the children were being treated and the children's parents signed an informed consent form prior to testing.

Data and error analysis

A total of 111 words with phonological errors were produced by the participants. Twenty-four of them resulted with an existing word and were excluded from the analysis (formal phonological errors, see footnote 5). In two cases, participants produced more than one phonological error for a target word (e.g. for the target word /ipaʁon/ 'pencil', one child responded: /paʁon . . . apeʁon/) – in these cases, each of the errors was counted and analysed separately. Therefore, the analysis included 87 erroneous responses (mean per child = 5.9 errors). The target words of these erroneous responses varied in length and frequency. The phonological errors included 166 phonological processes, which varied between 1–4 processes per word (see Table 1).

Table 1. Characteristics of the 87 target words.

Characteristics	Mean	Range
Length (number of phonemes)	6.10	3-10
Frequency (on a scale 1–7)	4.54	2.4–6.44
Number of phonological processes per word	1.9	1-4

The phonological errors were coded and classified as typical versus atypical phonological processes of Hebrew (Ben-David & Bat-El, 2016; Ben-David, 2015). Error types were coded by the three authors, reliability exceeded 95% and the few disagreements were resolved by consensus.

Classification of phonological processes

In the current study, we combined processes representing the Natural Phonology Theory with the hierarchical system of the Nonlinear Phonology Theory: segments, syllables and prosodic words. Thus, phonological processes of substitutions, assimilations and metatheses (transposition of sounds or syllables in a word, e.g. [tapish] for /patish/ 'hammer') were coded at the segmental level; omissions of segments (i.e. final consonant deletion or cluster simplification) were coded at the syllabic level; and syllable deletions were coded at the prosodic word level.

Typical processes – processes that are compatible with typical acquisition:

At the segmental level:

(a) Substitutions of a marked phoneme with an unmarked phoneme; with a change of only one feature compared to the target word: manner of articulation, place of articulation or voicing (e.g. [mi<u>s</u>vada] for /mi<u>z</u>vada/ 'suitcase' – a change in voicing).

(b) Assimilations – substitution of a segment with a segment that is similar to another segment in the word (e.g. [mimon] for /limon/ 'lemon').
(c) Metathesis – transposition of sounds or syllables in a word, most commonly two, or more, contiguous segments or syllables (e.g. [silma] for /simla/ 'dress').

At the syllabic level:

At the syllabic level:

Omission of segments due to their location in the syllable (although the child produced the segment in other words).

(a) Onset omission (e.g. [apit] for /kapit/ 'teaspoon').
(b) Omission of final coda (e.g. [maleg] for /mazleg/ 'fork').
(c) Cluster simplification – following the sonority hierarchy (e.g. [kisa] for /kvisa/ 'laundry'. For more details and exceptional examples, such as, [muna] for /tmuna/ 'picture', see Adi-Bensaid & Ben-David, 2010).

At the prosodic word level:

(a) Omission of unstressed syllable ([paʁon] for /ipaʁon/ 'pencil').

Atypical processes – processes that are *not* compatible with typical acquisition:

At the segmental level:

(a) Substitutions of an unmarked phoneme with a marked phoneme (e.g. voiced for unvoiced phoneme: [geshet] for /keshet/ 'rainbow').
(b) Substitutions that include a change of more than one feature compared to the target word (e.g. [magef] for /magets/ 'iron' – changing both manner and place of articulation).
(c) Vowel substitutions (e.g. [ʁidjo] for /ʁadjo/ 'radio'). These errors were classified as atypical because in Hebrew there are only five vowels, which are acquired before the second year of life (Ben-David, 2018).

At the syllabic level:

(a) Omission of the final coda while producing the medial coda (e.g. [maxʃe] for /maxʃev/ 'computer').
(b) Omission of the medial onset while producing the initial onset (e.g. [taregolet] for /tarnegolet/ 'chicken').
(c) Cluster simplification that violates the sonority hierarchy (e.g. [tuna] for /tmuna/ 'picture', Adi-Bensaid & Ben-David, 2010).

At the prosodic word level:

(a) Addition of a syllable to the target word (e.g. [batsale] for /batsal/ 'onion').

Note that the **typical phonological processes** were produced in the current study by children older than the typical age reported in the literature for these phonological processes (Ben-David, 2015, 2018, 2020; Ben-David & Bat-El, 2016). The term 'typical' in the current study refers to phonological processes that are presented in typically

developing Hebrew-speaking children younger than 3 years old (based on a sample of 1113 Hebrew speaking children aged 2;02–6;06, Ben-David, 2015). Thus, although these are typical processes, they are delayed. **The atypical phonological** processes are not seen in the productions of children with typical language development at any age.

Results

Within the 87 words with phonological errors, there were total of 166 phonological processes. Ten children showed typical and atypical phonological processes, and three children showed only atypical processes. In many cases, both typical and atypical processes occurred within the same word.

The first research question we wanted to answer focused on the phonological processes at the child level, predicting that each child would show more atypical phonological processes than typical ones. Most of the children (10 out of 13 children) showed more atypical phonological processes than typical ones (Figure 1), and the difference between these two types of processes was significant at the group level, using a Wilcoxon test ($z = 2.64$, $p = 0.008$, with a large effect size, Hedges' $g = 0.8$). Note that there was variability in the number of phonological processes produced by the children, with some children producing below 10 phonological processes, others producing between 10–20 phonological processes, and two children who produced more than 30 phonological processes.

Examining the question of typical versus atypical processes from a different angle, we tested the correlation between age and typical processes, assuming that decrease in typical

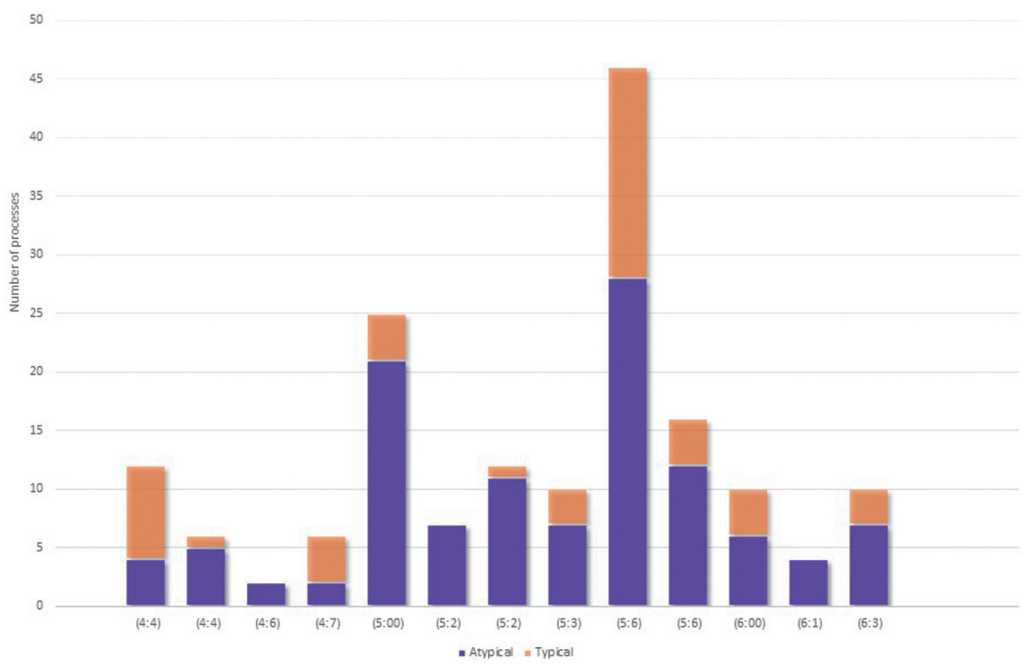

Figure 1. Number of typical and atypical phonological processes per child.

Table 2. Number of phonological processes (%).

	Typical	Atypical
Segmental level	26 (16%)	**80 (48%)***
Syllabic level	18 (11%)	14 (8%)
Prosodic word level	6 (4%)	**22 (13%)***

*Significant difference ($p < 0.05$).

processes with age (between age 4 and 6 years old as shown in Ben-David, 2015) would support typical acquisition. However, no significant correlation was shown between age and typical processes (r = 0.04, $p = 0.44$).

The second research question we wanted to answer focused on the three phonological levels (segment, syllable and word) at the group level, predicting that more atypical phonological processes would appear at each level compared with typical ones (Table 2). The findings, using a Wilcoxon test, revealed significantly more atypical processes at the segmental level (z = 2.49, $p = 0.012$, with a large effect size, Hedges' g = 0.9) and at the prosodic word level (z = 2.04, $p = 0.041$, with a large effect size, Hedges' g = 0.9), but not at the syllabic level (z = 0.86, $p = 0.38$, with a small size effect size, Hedges' g = 0.15).

Discussion

In this research we explored phonological errors produced by preschool children with DLD in a picture naming task, characterising the phonological processes of these errors. The analysis revealed typical processes (portraying younger children with typical phonological acquisition, compared to the children tested in the current study), as well as atypical processes. In both comparisons, the child level and the three phonological levels, more atypical phonological processes were observed, except for the syllabic level. It is important to note that the children in the current study were not diagnosed with SSD and that the number of words that reveal problems in the phonological process that were produced per child was small. At the surface level, one can argue that these children do not represent individuals with phonological disorders. Nevertheless, we suggest that the characteristics of the errors, specifically the atypical processes, support impairment in the phonological representations of the participants (Leitão & Fletcher, 2004; Munson et al., 2005; Orsolini et al., 2001).

A delay in phonological acquisition might manifest in systematic error patterns that are typical in the speech of younger children and are resolved with age. Note that this pattern was not shown in the DLD group tested in the current study, because they were all older than the age at which these phonological processes usually appear (Ben-David, 2015, 2018). Moreover, no significant decrease of typical processes with age was shown. Although the participants were not diagnosed with SSD, they showed a difficulty in using phonemes that they had already acquired and produced correctly in other words.

Furthermore, our findings present errors that are not typical of phonological acquisition (Ceron et al., ; McLeod & Baker, 2017). The phonological processes were shown in short and long words and in frequent and infrequent words (see Table 1). While in typical phonological acquisition, word length and frequency show an effect (e.g. Braginsky et al., 2019 for 10 different languages); in atypcial acquisition

inconsistency is common (e.g. Rvachew & Matthews, 2019). Our results are in line with previous studies showing inconsistency of phonological knowledge (Leitão & Fletcher, 2004; Rvachew & Matthews, 2019). However, note that we discuss frequency of words roughly and we did not test the frequency effect directly. Thus, the existence of a frequency effect remains open for future studies.

As was noted in the results, in many cases both typical and atypical processes occurred within the same word. For example, one child (aged 5:06 years old) produced the target word /magʁefa/ 'rake' as [mapexa], in which the medial coda omission (/g/) is a typical phonological process for younger children, while the segment substitutions are atypical (/p/ instead of /ʁ/ and /x/ instead of /f/; both substitutions involve a change of more than one feature). Together, these findings support an impairment in the phonological representations, although the children in the current study were diagnosed with DLD and not with SSD. This finding was very clear despite the small number of participants.

The variability in the number of atypical phonological processes produced by the children in the current study opens a question regarding the severity of the deficit. It could be that the number of phonological processes represent the severity of the impairment. Future studies, including perception tasks and additional production tasks (e.g. nonword repetition), in addition to the error analysis discussed here are required. These will also allow exploring explanations of storage deficits and access to phonological representations.

In addition to the atypical and less predictable error types, the current findings showed inconsistent production of the same target word. For example, one child produced [peʁon] and [apeʁon] for /iparon/ 'pencil'). It is suggested that children with expressive phonological delay often possess poor underlying perceptual knowledge of the sound system and show delayed development of segmental organisation (Rvachew et al., 2004). Deficits in phoneme perception at the syllabic level of children with SSD is also shown for phonemes that these children could produce (e.g. Cummings et al., 2020), supporting the existence of immature neural networks for processing of speech sounds. It is suggested that the impaired phonological system might not allow children with SSD full and accurate processing and discrimination of phonological information, which might also result in inconsistent phonological representation and production of words they have in their lexicon. Support for this assumption is shown in Dodd's et al. (2018) findings. In their longitudinal study of children with SSD, those who showed atypical errors were not resolved after three years compared with those who showed typical errors. They defined atypical errors as errors that appear less than 10% in normative samples and in inconsistent production of the same lexical item. The current findings of inconsistent production of the same target word and across words show a similar pattern of atypical phonological representation for children with DLD.

Finally, whereas at the segmental and prosodic word level there was a significant difference between typical versus atypical phonological processes, at the syllabic level, this pattern was not shown. Orsolini et al. (2001) showed that Italian speaking children with DLD had difficulties with complex syllabic structures, resulting in cluster simplification. The researchers suggested that this type of error is a strong indicator for a phonological disorder versus phonological delay. This pattern of errors was not shown in our data, in addition to low percentage of phonological processes at the syllabic level (typical and

atypical), including cluster simplifications. One possible explanation for the gap between Orsolini et al. (2001) findings and ours is the specific language characteristics of clusters in Italian. Some clusters in Italian have special sounds, which are different from the simple combination of the two consonants they consist of. This unique characteristic of the language requires additional phonological learning and might cause an extra burden for children with DLD. In contrast, Hebrew's clusters preserve the independent pronunciation of its consonants (e.g. the cluster */kf/* in the word */kfafa/* [meaning 'glove'] is pronounced as *k+f*). This difference between Italian and Hebrew supports the importance of understanding and describing typical and atypical phonological processes separately in each language.

The current findings raise an important clinical issue regarding the differential diagnosis between childhood apraxia of speech (CAS) and phonological disorders. Canault et al. (2020) followed a French-speaking child with CAS for two years between 5–7 years old, and found a difficulty in producing the syllabic structure. In a study examining 16 Hebrew-speaking children with CAS, 2:07-5:06 years old, a-synchronisation was found between the prosodic word level and the syllabic and segmental levels, with the prosodic word level developing more quickly than the two other levels. This a-synchronisation manifests in many *omissions*, sometimes producing only the vowels (e.g. [o.o.u] for /otobus/ 'bus') and is explained by difficulty in motor planning in the transitions between segments and syllables (Tubul-Lavy, 2012). In contrast to CAS, the children in the current study showed many *substitutions* at the segmental level (64%). This finding suggests that in a phonological disorder the skeleton of the word is retained but the different segments do not match the target word. For example, one child produced the target word [tsdafim] 'shells') as [svatim], keeping the prosodic skeleton of the word [CCVCVC] with three substitutions in the segmental level: /s/ for /ts/, /v/ for /d/, and /t/ for /f/). Children with phonological disorders do not have motoric problems, but they might not have the correct representation of the word's segments, leading to assimilations, metatheses and consonant substitutions. Bradford (2000) suggested that children with phonological disorders show unpredictable and atypical speech errors because of the deficit at the level of constructing, storing and/or retrieving the phonological output plan. Thus, the number of 'slots' for syllables or segments within syllables might be filled with the wrong phonemes or in the wrong order. These children may also exhibit difficulties in retrieving the phonological representation of words and will have deficits in word naming as suggested by Rvachew and Matthews (2019). The children in the current study were diagnosed as having DLD with deficits in word naming and we showed that they also present deficits in their phonological abilities. These findings link deficits in word naming and deficits in retrieval of the phonological representation, supporting Rvachew and Matthews's (2019) notion.

Conclusions and implications

Our findings show that the phonological errors of children with DLD represent atypical phonological processes at both the child level (across different phonological levels) and in two phonological levels, segmental and prosodic word. These atypical processes are shown for all children in addition to typical processes (which are beyond the expected chronological age). Even in a small number of words with phonological errors, as shown

in the current study, the characteristics of these errors suggest a phonological deficit. This deficit affects word production and can later affect reading and writing capacities (e.g. Leitão & Fletcher, 2004). Thus, it is recommended that phonological error analysis should be included as part of production assessment of children with DLD. We suggest that the atypical phonological error patterns of children with DLD characterise selective impairment in the representation and use of their phonology.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Michal Biran http://orcid.org/0000-0001-7539-9085
Rama Novogrodsky http://orcid.org/0000-0002-9834-2388

References

Adi Bensaid, L., & Ben David, A. (2010). Typical acquisition by atypical children: Initial consonant cluster acquisition by Israeli Hebrew-acquiring children with cochlear implants. *Clinical Linguistics & Phonetics*, *24*(10), 771–794. https://doi.org/10.3109/02699206.2010.498932

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. American Psychiatric Publishing.

Anjarningsih, H. Y., & Puryanti, F. (2022). A preliminary study: Word and non-word repetition tasks in children with speech delay. *International Review of Humanities Studies*, *7*(1), 141–154. https://doi.org/10.7454/irhs.v7i1.397

Anthony, J. L., Aghara, R. G., Dunkelberger, M. J., Anthony, T. I., Williams, J. M., & Zhang, Z. (2011). What factors place children with speech sound disorders at risk for reading problems? *American Journal of Speech and Language Pathology*, *20*(2), 146–160. https://doi.org/10.1044/1058-0360(2011/10-0053)

Baker, E., & McLeod, S. (2004). Evidence-Based management of phonological impairment in children. *Child Language Teaching and Therapy*, *20*(3), 261–285. https://doi.org/10.1191/0265659004ct275oa

Ben David, A. (2015). Norms in Hebrew phonological acquisition. *The Israeli Journal of Language, Speech & Hearing Disorders*, *34*, 1–13. (Hebrew).

Ben David, A. (2018). Acquisition of Hebrew phonology. In G. Tubul-Lavy & H. Putter-Katz (Eds.), *Speech sound disorders in Hebrew: Theoretical issues and clinical implications* (pp. 18–47). Yesod. (Hebrew).

Ben David, A. (2020). Phonological development in Hebrew: A normative cross-sectional study. In E. Babatsouli (Ed.), *On under-reported monolingual child phonology* (pp. 77–98). Multilingual Matters.

Ben David, A., & Bat-El, O. (2016). Paths and stages in acquisition of the phonological word in Hebrew. In R. Berman (Ed.), *Acquisition and development of Hebrew: From infancy to adolescence* (pp. 39–68). John Benjamins.

Bernhardt, B., & Stoel-Gammon, C. (1994). Nonlinear phonology: Introduction and clinical application. *Journal of Speech, Language, and Hearing Research*, *37*(1), 123–143. https://doi.org/10.1044/jshr.3701.123

Biran, M., & Friedmann, N. (2004). *SHEMESH: Naming a hundred objects*. Tel Aviv University.

Biran, M., & Friedmann, N. (2005). From phonological paraphasias to the structure of the phonological output lexicon. *Language and Cognitive Processes*, *20*(4), 589–616. https://doi.org/10.1080/01690960400005813

Biran, M., Novogrodsky, R., Harel-Nov, A., Gil, M., & Bloch, A. (2018). What we can learn from naming errors of children with language impairment at preschool age. *Clinical Linguistics & Phonetics*, *32*(4), 298–315. https://doi.org/10.1080/02699206.2017.1365096

Bishop, D. V. (2014). *Uncommon understanding (classic edition): Development and disorders of language comprehension in children*. Psychology Press.

Bishop, D. V., Snowling, M. J., Thompson, P. A., & Greenhalgh, T. (2016). CATALISE: A multinational and multidisciplinary Delphi consensus study. Identifying language impairments in children. *PLoS One*, *11*(7), e0158753. https://doi.org/10.1371/journal.pone.0158753

Bradford, B. D. A. (2000). A comparison of three therapy methods for children with different types of developmental phonological disorder. *International Journal of Language & Communication Disorders*, *35*(2), 189–209. https://doi.org/10.1080/136828200247142

Braginsky, M., Yurovsky, D., Marchman, V. A., & Frank, M. C. (2019). Consistency and variability in children's word learning across languages. *Open Mind*, *3*, 52–67. https://doi.org/10.1162/opmi_a_00026

Canault, M., Thai-van, H., & Le Normand, M. T. (2020). Simplification of syllable structure in childhood apraxia of speech: A 2-year follow-up French case study. *Clinical Linguistics & Phonetics* 35(10) , 945–963.

Ceron, M. I., Gubiani, M. B., Oliveira, C. R. D., Gubiani, M. B., & Keske-Soares, M. (2017). Prevalence of phonological disorders and phonological processes in typical and atypical phonological development. *CoDas*, *29*(3), 1–9.

Cummings, A. E., Ogiela, D. A., & Wu, Y. C. (2020). Evidence for [coronal] underspecification in typical and atypical phonological development. *Frontiers in Human Neuroscience*, *14*, 1–20. https://doi.org/10.3389/fnhum.2020.580697

Degani, T., Kreiser, V., & Novogrodsky, R. (2019). The joint effects of bilingualism, DLD and item-frequency on children's lexical retrieval performance. *International Journal of Language and Communication Disorders*, *54*(3), 485–498. https://doi.org/10.1111/1460-6984.12454

Dockrell, J. E., Messer, D., George, R., & Wilson, G. (1998). Children with word finding difficulties – prevalence, presentation and naming problems. *International Journal of Language and Communication Disorders*, *44*(4), 445–454 .

Dodd, B., Ttofari-Eecen, K., Brommeyer, K., Ng, K., Reilly, S., & Morgan, A. (2018). Delayed and disordered development of articulation and phonology between four and seven years. *Child Language Teaching and Therapy*, *34*(2), 87–99. https://doi.org/10.1177/0265659017735958

Donegan, P., & Stampe, D. (1979). The study of natural phonology. In D. Dinnsen (Ed.), *Current approaches to phonological theory*. Indiana University Press.

Edwards, J., Munson, B., & Beckman, M. E. (2011). Lexicon-Phonology relationships and dynamics of early language development. *Journal of Child Language*, *38*(1), 35–40. https://doi.org/10.1017/S0305000910000450

Estes, K. G., Evans, J. L., & Else-Quest, N. M. (2007). Differences in the nonword repetition performance of children with and without specific language impairment: A meta-analysis.

Faust, M., Dimitrovsky, L., & Davidi, S. (1997). Naming difficulties in language-disabled children: Preliminary findings with the application of the TOT paradigm. *Journal of Speech, Language, and Hearing Research*, *40*(5), 1026–1036. https://doi.org/10.1044/jslhr.4005.1026

Friedmann, N., & Novogrodsky, R. (2011). Which questions are most difficult to understand? The comprehension of Wh questions in three subtypes of SLI. *Lingua*, *121*(3), 367–382. https://doi.org/10.1016/j.lingua.2010.10.004

Gendler-Shalev, H., Ben David, A., & Novogrodsky, R. (2021). The effect of phonological complexity on word order acquisition in early childhood. *First Language*, *41*(6), 779–793. https://doi.org/10.1177/01427237211042997

German, D. J., & Newman, R. S. (2004). The impact of lexical factors on children's word-finding errors. *Journal of Speech, Language, and Hearing Research*, *47*(3), 624–636. https://doi.org/10.1044/1092-4388(2004/048)

Grunwell, P. (1982). *Clinical phonology*. Aspen Systems Corp.

Grunwell, P. (1985). Developing phonological skills. *Child Language Teaching and Therapy*, *1*(1), 65–72. https://doi.org/10.1177/026565908500100108

Ingram, D. (1976). *Phonological disability in children*. Arnold.

Ingram, D. (1986). Phonological development: Production. In P. Fletcher & M. Garman (Eds.), *Language acquisition* (2nd ed.). Cambridge University Press.

Ingram, D. (1989). *First language acquisition. Method, description, and explanation*. Cambridge University Press.

Joffe, V., & Pring, T. (2008). Children with phonological problems: A survey of clinical practice. *International Journal of Language & Communication Disorders*, *43*(2), 154–164. https://doi.org/10.1080/13682820701660259

Leitão, S., & Fletcher, J. (2004). Literacy outcomes for students with speech impairment: Long-term follow-up. *International Journal of Language & Communication Disorders*, *39*(2), 245–256. https://doi.org/10.1080/13682820310001619478

Leonard, L. B. (2014). *Children with specific language impairment*. MIT press.

Lewis, B. A., Freebairn, L. A., & Taylor, H. G. (2000). Academic outcomes in children with histories of speech sound disorders. *Journal of Communication Disorders*, *33*(1), 11–30. https://doi.org/10.1016/S0021-9924(99)00023-4

McGregor, K. K. (1994). Use of phonological information in a word-finding treatment for children. *Journal of Speech, Language, and Hearing Research*, *37*(6), 1381–1393. https://doi.org/10.1044/jshr.3706.1381

McGregor, K. K. (1997). The nature of word-finding errors of preschoolers with and without word finding deficits. *Journal of Speech, Language, and Hearing Research*, *40*(6), 1232–1244. https://doi.org/10.1044/jslhr.4006.1232

McLeod, S., & Baker, E. (2017). *Children's speech: An evidence-based approach to assessment and intervention*. Pearson.

McLeod, S., & Crowe, K. (2018). Children's consonant acquisition in 27 languages: A cross-linguistic review. *American Journal of Speech-Language Pathology*, *27*(4), 1546–1571. https://doi.org/10.1044/2018_AJSLP-17-0100

Messer, D., & Dockrell, J. E. (2006). Children's naming and word-finding difficulties: Descriptions and explanations. *Journal of Speech, Language, and Hearing Research*, *49*(2), 309–324. https://doi.org/10.1044/1092-4388(2006/025)

Munson, B., Edwards, J., & Beckman, M. E. (2005). Relationships between nonword repetition accuracy and other measures of linguistic development in children with phonological disorders. *Journal of Speech, Language, and Hearing Research*, *48*(1), 61–78. https://doi.org/10.1044/1092-4388(2005/006)

Nathan, L., Stackhouse, J., Goulandris, N., & Snowling, M. J. (2004). The development of early literacy skills among children with speech difficulties: A test of the "critical age hypothesis.". *Journal of Speech, Language, and Hearing Research*, *47*(2), 337–391. https://doi.org/10.1044/1092-4388(2004/031)

Novogrodsky, R., & Kreiser, V. (2015). What can errors tell us about specific language impairment? Semantic and morphological cuing in a sentence completion task. *Clinical Linguistics & Phonetics*, *29*(11), 812–825. https://doi.org/10.3109/02699206.2015.1051239

Novogrodsky, R., & Kreiser, V. (2019). Children with developmental language disorders (DLD) in Israel - assessment and intervention. In J. Law, C. Murphy, C. McKean, & E. P. Þórðardóttir (Eds.), *The theory and practice of managing the child with language impairment- across Europe and beyond*. (pp. 285-301). Routledge publication.

Orsolini, M., Sechi, E., Maronato, C., Bonvino, E., & Corcelli, A. (2001). Nature of phonological delay in children with specific language impairment. *International Journal of Language & Communication Disorders*, *36*(1), 63–90. https://doi.org/10.1080/13682820150217572

Pascoe, M., Maphalala, Z., Ebrahim, A., Hime, D., Mdladla, B., Mohamed, N., & Skinner, M. (2010). Children with speech difficulties: A survey of clinical practice in the Western Cape. *South African Journal of Communication Disorders*, *57*(1), 66. https://doi.org/10.4102/sajcd.v57i1.51

Rescorla, L. A. (2013). Late-Talking Toddlers: A 15-year follow-up. In L. A. Rescorla & P. H. Dale (Eds.), *Late talkers* (pp. 219–240). Brookes Publishing.

Rvachew, S., & Matthews, T. (2019). An N-of-1 randomized controlled trial of interventions for children with inconsistent speech sound errors. *Journal of Speech, Language, and Hearing Research*, *62*(9), 3183–3203. https://doi.org/10.1044/2019_JSLHR-S-18-0288

Rvachew, S., Nowak, M., & Cloutier, G. (2004). Effect of phonemic perception training on the speech production and phonological awareness skills of children with expressive phonological delay. *American Journal of Speech-Language Pathology*, *13*(3), 250–263. https://doi.org/10.1044/1058-0360(2004/026)

Stampe, D. (1969, April). The acquisition of phonetic representation. *Proceedings from the Annual Meeting of the Chicago Linguistic Society* (Vol. 5, No. 1, pp. 443–454). Chicago Linguistic Society.

Stoel-Gammon, C. (2011). Relationships between lexical and phonological development in young children. *Journal of Child Language*, *38*(1), 1–34. https://doi.org/10.1017/S0305000910000425

Sutherland, D., & Gillon, G. T. (2005). Assessment of phonological representations in children with speech impairment. Language, Speech & Hearing Services in Schools, *Speech & Hearing Services in Schools*, *36*(4), 294–307. https://doi.org/10.1044/0161-1461(2005/030)

Tubul Lavy, G. (2012). Intra-Word inconsistency in apraxic Hebrew-speaking Children. *Linguistics and Phonetics*, *26*(6), 502–517.

Tubul Lavy, G., Nachamani, A., & Adi Bensaid, L. (2018). Clinical practice of Israeli speech and language therapists with children with speech sound disorders: The gap between ideal and actual practice. In E. Babatsouli (Ed.), *Cross-Linguistic research in monolingual and bilingual speech* (pp. 271–289). Equinox Publishing.

Viterbori, P., Zanobini, M., & Cozzani, F. (2018). Phonological development in children with different lexical skills. *First Language*, *38*(5), 538–559. https://doi.org/10.1177/0142723718784369

Weismer, S. E., Tomblin, J. B., Zhang, X., Buckwalter, P., Chynoweth, J. G., & Jones, M. (2000). Nonword repetition performance in school-age children with and without language impairment. *Journal of Speech, Language, and Hearing Research*, *43*(4), 865–878. https://doi.org/10.1044/jslhr.4304.865

Appendix A

Error type analysis in the SHEMESH naming test - children with DLD and children with typical language development (Biran et al., 2018)

In the original study (Biran et al., 2018), two groups of children were examined: 16 children with DLD and 30 control participants with typical language development (mean age: 5;03 and 4;10, respectively; no significant difference between groups' chronological age, $p > 0.05$).

The SHEMESH naming test (Biran & Friedmann, 2004) was administered to the children in both groups, and their errors were analysed using the SHEMESH test criteria.

Therefore, errors were classified into the following types: semantic, description, definition, phonological, gesture, 'don't know' response, hesitation and other. The rate of errors of each type at the two groups are presented in the Table below.

Ratio of error types (%) of the children with DLD and typical language development [a] (Taken from Biran et al., 2018)

Error type	DLD (SD)	Typical Language Development (SD)	Mann-Whitney test
Semantic	35 (9)	54 (15)[b]	$z = 4.01$, $p < 0.0001$
Description	22 (9)	12 (10)	$z = 3.21$, $p = 0.001$
Definition	3 (3)	1 (3)	$z = 1.28$, $p = 0.2$
Phonological	18 (11)	1 (3)	$z = 5.07$, $p < 0.0001$
Gesture	3 (3)	0 (1)	$z = 3.87$, $p < 0.001$
'Don't know'	6 (6)	14 (13)	$z = 1.79$, $p = 0.07$
Hesitation	5 (6)	4 (10)	$z = 1.72$, $p = 0.09$
Other	8 (5)	14 (11)	$z = 1.71$, $p = 0.09$

[a]The ratio of each error type was calculated as the number of errors per type out of the total number of errors produced by the children in each group; thus, for each group, error types add up to 100%.
[b]Shaded cells indicate a significant difference between groups.

In the analysis of error types, all responses for each target noun were analysed. For example, for the target word '*GAFRUR' (match)*, one of the participants responded sequentially: *(1) "ET" (pen)* – a visual error, *(2) "MAFUR"* – a phonological error, *(3) "MASOR" (saw)* – an unrelated error, and *(4)* '*to light candles on the Sabbath'* – a description. Errors were calculated as total errors per type among total errors by each participant.

Importantly, to rule out familiarity effects on naming, when children responded, 'I don't know', the word was presented to them auditorily at the end of the test (for example, 'What is an anchor?'). If children said they did not know the word, it was eliminated from the total number of words and was not counted as a naming error. Namely, for some of the children, the total target words in the naming test was less than 100 (see Appendix B). However, the number of words that were excluded for each child because they were unfamiliar was small and varied form 0-8, mean = 1.75). The findings revealed that children with DLD had lower naming scores and produced different error patterns compared to the control group.

Appendix B

Participants' performance in the SHEMESH naming test

Participant	Age	Sex	% Correct (num. correct/total num. of target words)[a]
DS	4;04	M	70 (69/98)
YY	4;04	M	43 (42/97)
DB	4;06	M	48 (48/100)
YV	4;07	M	58 (58/100)
AZ	5;00	M	65 (63/97)
AD	5;02	M	66 (65/99)
ST	5;02	M	53 (52/98)
EK	5;03	M	74 (74/100)
MK	5;06	M	47 (46/98)
RH	5;06	M	63 (63/100)
AK	6;00	F	67 (67/100)
AA	6;01	F	67 (64/96)
YL	6;03	F	74 (73/98)

[a]In cases when the child was not familiar with a word in a post-hoc comprehension task, the word was eliminated from the total number of target words. Therefore, for some of the children the total number of target words in the naming test was less than 100. (See Appendix A.).