Research Article

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Journal of Childhood & Developmental Disorders
ISSN 2472-1786

2021
Vol.7 No.7:4

The Case for Detailed Profiling in Disordered Speech Systems

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Citation: Bates S (2021) The Case for Detailed Profiling in Disordered Speech Systems. J Child Dev Disord Vol.7 No.7.4

Abstract

This paper has the aim of reinvigorating interest in the collection of detailed longitudinal data of children's speech development. Our primary motivation is clinical. We feel that a better understanding of the trajectory of both typical and disordered development, where consonant and vowel systems are given equal consideration, would inform prognosis and more effective, efficient intervention. We begin our argument by outlining the information provided by the current approach to clinical assessment. We then examine additional benefits to be gained by using a contrastive, system wide analysis to capture the dynamic interplay between error patterns themselves and potential linguistic and environmental constraints. Note that in our description of speech examples we hold to the usual conventions whereby the orthography of the word is presented in inverted commas, the target pronunciation and speaker's actual utterance are phonetically transcribed and presented within slanted brackets // and square brackets [] respectively. We hope that the examples used mean the points of the argument are readily accessible eg 'computer', /kəmputə/, [putə]. We have also used examples of speech reflecting either standard southern English or standard Scottish as the target accent. We have though selected error patterns which focus on areas of commonality across any English accent rather than those on which the more distinctive features rest.

Keywords: Early development; Clinical speech; Velar fronting

Received date: July 09, 2021; **Accepted date:** July 23, 2021; **Published date:** July 30, 2021

Introduction

Currently the favored analytical approach in the clinical assessment of children's speech involves identifying error patterns or 'phonological processes' within the developing system which need to resolve before the mature adult system is fully in place. Analysis is based on a transcribed speech sample, obtained by asking the child to name a series of pictures which have been selected to prompt a balanced phonetic sample with most sounds in the target language represented at least once. Comparison with normative data allows identification of children presenting with age appropriate, delayed or disordered speech [1,2]. A distinction is made between phonological processes which occur naturally in early typical development and atypical processes which are considered indicative of disordered development. To illustrate, a common natural process in English, 'velar fronting' involves the child using the tongue tip closed against the alveolar ridge (behind the top teeth) to pronounce a class of sounds which are normally made by raising the back of the tongue to close against the velar region of the palate. This results in the target velar plosives /k, g/ and nasal /ŋ/ (as in ring) being heard as their alveolar counterparts, respectively [t, d] and [n]. The corollary, 'alveolar backing' refers to a process whereby alveolar sounds are pronounced with a velar articulation resulting in /t, d/ and /n/ pronounced respectively as [k, g] and nasal [ŋ]. This is less commonly reported as a feature of typical early development and its presence in clinical speech is regarded as redolent of a disorder. Both error patterns are regarded as being phonological in nature since the inability to make a phonetic (ie articulatory) contrast between velar and alveolar consonants results in reduced ability to signal the meaning differences which rely on this distinction. For example, with velar fronting, both 'bat' and 'back' are pronounced as [bat]; 'bad' and 'bag' as [bad] and 'bang' and 'ban' as [ban]. Similarly 'tea' and 'key' would be pronounced as [ti] and 'dough' and 'go' as [dəu]. Note that these phonological processes are distinct from articulatory errors or 'phonetic distortions' such as 'lisps' where the target sound is replaced by a sound which does not feature in the adult target system. The speech may consequently sound unusual, with the potential for a negative social impact but intelligibility is largely preserved [3].

In addition to informing differential diagnosis, process analysis allows a notion of severity to be derived. The degree to which a child's speech is compromised depends on the number of processes simultaneously in play and by the length of time a process persists beyond the expected time of resolution. Severity can also be captured by quantitative measures such as percent consonant correct (PCC) and percent whole word correct (PWC) [4]. These have the merit of summarizing the system in a single score and so are considered a useful way of measuring the speech development of large cohorts and for demonstrating the effectiveness of intervention.

Methods

While these analysis tools have clearly delivered important and useful information in both research and clinical work, the information derived tends to imply that processes/patterns apply across the sound system universally ie affect all instances where the affected phonemes appear in the target speech. We already know however that the application of a given phonological process/pattern at any one assessment point is often variable and may depend on linguistic constraints such as the position the target sound occupies in the word (ie syllable initial or final) and the identity of other sounds (vowels and consonants) within the word. Lexical factors such as word length, word frequency and word familiarity are also influential. As is the maturity of the child's underlying speech processing skills when they first 'learn'/ encounter a given word. How well is the child able to refine/ update information about a word's sound pattern with repeated experience of the word and as their speech perception and production skills develop. To illustrate let us return to our example of velar fronting. In typical development /k/, /g/ and /ŋ/ tend to be mastered in word final position before word initial position. 'Pack' may therefore be correctly pronounced [pak] while at the same time the initial velar consonant in 'car' may be fronted [tɑ]. This conditioning effect is not revealed if the sample does not contain words where the conditioning pattern can be expressed ie words where the velar sound is at the beginning of and words where velars are word final.

Pronunciation can also be affected by the presence of other sounds in the target word. We know that velar production can be facilitated by the quality of the following vowel [5]. /k/ and /g/ may be pronounced correctly if followed by a vowel made with a low or mid low back tongue position eg /ɑ/ - but fronted to [t] and [d] preceding a vowel requiring a high front tongue position such as /i/ (the vowel in 'bee'). So a child sensitive to this influence would pronounce 'car' as [kɑ] but 'key' as [ti]. The consonantal context can also be an influencing factor. Velar plosives which are typically correct within the child's system may be 'fronted' if there are other alveolar consonants in the word. For example, 'car' or 'carp' might be pronounced correctly /kɑ/ and /kɑp / but 'cart' and 'card' pronounced respectively as [tɑt] and [dɑd]. In some children this process may occur in all words where the operating condition applies, but for other children only emerge in more demanding, multi syllabic contexts. So an iconic Scottish bird - 'capercaillie' / kapəkɛili/ could be pronounced correctly but 'caterpillar' /katəpɪlə/ incorrectly [tatəpɪlə].

These conditioning contexts may be fleetingly influential in typical development but can persist in delayed/disordered development. The important point is that limited analysis of a small speech sample may lead to the false conclusion that a child's production of velars is consistently absent or present or randomly variable whereas in fact the production might be variable but consistently so and in clinical cases persistently so. Taking a system wide view is helpful. To illustrate let us consider the question of 'consonant harmony'. As the name suggests, this is an assimilatory pattern whereby the target consonant is pronounced in the same or a similar way to another sound within the word. It is not unlike the context conditioning described above except with the important proviso that the errored pronunciation reflects difficulty achieving a phonetic contrast within a particular word rather than the system as a whole, ie across all words which contain the target consonants. Common examples include 'cat' /kat/ ⍰[tat], 'dog' / dɒg/ ⍰[gɒg] or 'duck' /dʌk/ ⍰[gʌk].

Consonant Harmony is a characteristic feature of very early typical development and instances can persist as habitual or 'fossilised' forms in delayed/disordered systems. It is therefore entirely possible that a child who consistently fronts velars will also pronounce /dɒg/ as [gɒg]. We might be forgiven for thinking the child is both fronting and backing and, furthermore, given the presence of an atypical pattern in their system, that they have a phonological disorder. If, however, we take a system wide view and look at the general pattern of production across both sound classes (velar and alveolar), this instance will stand out as an anomaly prompting us to revisit the word in question and recognise the error as an example of consonant harmony, so avoiding potential misdiagnosis. Again, of course, our analysis is only be as good as our speech sample so it is important for it to contain more than one or two tokens of the sounds of interest. Consonant harmony relating to the alveolar vs velar place distinction is among the most common in both typical and atypical systems and can be easily missed. Harmony between velar or alveolar sounds and sounds made at the lips, eg /p, b/ as in 'cup' /kʌp/ ⍰[pʌp] or which cross a major sound class distinction such as oral vs nasal, as in 'farmer' / fɑmə/ ⍰[mɑmə] are less phonetically principled and are therefore more easily spotted.

The examples so far have related to the variable treatment of the same target consonants, ie velars /k, g, ŋ/, across different words or lexical items. Another kind of variability relates to the inconsistent production of the same word/lexical item across different repetitions. For example, 'caterpillar' /katəpɪlə/ may be pronounced variably as [tatəpɪlə], [takəpɪlə], [patəkɪlə]. This type of inconsistency is a diagnostic feature of a sub group of SSD – Inconsistent Speech Disorder (ISD) and is also associated with Childhood Apraxia of Speech (CAS) [3,6]. The underlying cause of the inconsistency is presumed to be different in each case, with a perceptual basis in the case of ISD [7] and a motor basis in the case of CAS (although perception may be implicated here too) [2]. The impact on intelligibility can be severe since the errors are not systematic and hence not predictable. Rather they pertain at the level of the individual word and may be mediated by performance factors such as fatigue, increased linguistic processing demands (eg grammatical complexity) and/or social anxiety. Inconsistency of this kind requires a different therapeutic approach than that routinely taken in cases of phonological delay/disorder. It is therefore important that context conditioned variability which is phonetically principled and often evidence of progressive change within the system is not confused with this type of non-progressive variability. However, even this is not entirely straightforward. Take the example of torch' /tɔtʃ/ pronounced variably as [dɔt], [tɔt] and [tɔts]. While we ostensibly have variable treatment of the same word, a more detailed analysis of the data might suggest progression. In the last token, /ʧ/ is pronounced as [ts] which, although not a phoneme of English is closer in terms of its phonetic properties to the target 'ch' than [t]. This example nicely illustrates the fact that not all errors are equal, an important point that is missed in PCC scores. It also further illustrates the importance of extending the scope of the analysis to find evidence to support or refute this hypothesis, ie how does the child pronounce /ʧ/ in other words? How do they pronounce /ʤ/, the voiced counterpart to /ʧ/?

The picture becomes again more complex where, as is typically the case in more severely unintelligible speech, multiple error processes are operating in parallel. For example, a child who fronts velars may also have difficulty in producing fricative consonants, instead substituting with plosives. The fricatives /f, v, s, z / would be pronounced respectively as [p, b, t, d]. These processes also commonly interact with another process: 'context sensitive voicing'. 'Voiceless' consonants such as /p, t, k, f, s/ are voiced where they occur before a vowel and 'voiced' consonants such as /b, d, g, v, z/ are 'de-voiced' word finally. An interaction of velar fronting and pre-vocalic voicing would result in target words such as 'cake' /kɛik/ being pronounced as 'date' [dɛit], ie /k/ → [t] → [d] word initially and /k/ → [t] word finally. An interaction of velar fronting and post-vocalic devoicing would result in target 'bag' [bag] being pronounced as 'bat' [bat], /g/ → [d] → [t]. An example of stopping and pre-vocalic voicing would be the target word 'fan' /fan/ being pronounced as 'ban' [ban], ie /f/ ⍰[p] ⍰[b]. Again, any one of these processes – velar fronting, stopping, context sensitive voicing, may apply 100% wherever the candidate sounds occur or variably depending on the influence of other linguistic constraints or the extent to which these are already moving towards resolution.

So far we have used the operation of phonological processes affecting consonant production and the potential consequences of their interaction to highlight complexities within the developing system. In this section we turn our attention to vowels. Described as "the poor relations in child phonology" [5], vowels have received relatively little attention in the literature as compared to consonants, from the perspective of either typical or atypical development. Seminal research which included individual case studies and case series in the 1990's [8] drew our attention to the fact that vowels may not only serve as potential conditioning environments for consonant errors but may be problematic in their own right.

Importantly these and the small number of subsequent studies [9] have shown that vowel errors may be described in similar phonological process terms to those used for consonant error patterns. The same distinction can also be drawn between these phonological patterns and phonetic distortions which result in a sound which does not feature in the adult target system. This is important as recent cohort evidence suggests that while systematic error patterns feature in both CAS and phonological disorder, vowel distortions, eg excessive lengthening, nasalisation, mis-articulations would seem only to feature in CAS [3]. There is also recent evident from a large cohort study [7] that vowel errors are one of the two key markers, alongside consonant cluster reduction (eg. 'clowd', /klaud/, [kaud]), distinguishing typically developing children from those with speech difficulties at 8;0.

Traditionally vowel systems are depicted graphically using a vowel quadrilateral. This format can also be used to provide an 'at a glance' understanding of vowel errors operating across the whole system and to track development within the system. The main features of the approach are shown in **Figure 1** where a vowel quadrilateral containing the monophthongs of a standard Southern English (SBS) accent is superimposed on the oral cavity. An orthographic reference word for each monophthong is provided below. (Note – vowel systems of English contain both monophthongal vowels and diphthongs. Compare 'bee' - monophthong /i/ with 'add' monophthong /a/ with 'sky' diphthong /ai/. For simplicity we confine our argument here to examples based on the monophthongal system. Further description of vowel error patterns including the diphthongal systems are provided in CAVES http://sites.marjon.ac.uk/caves/.)

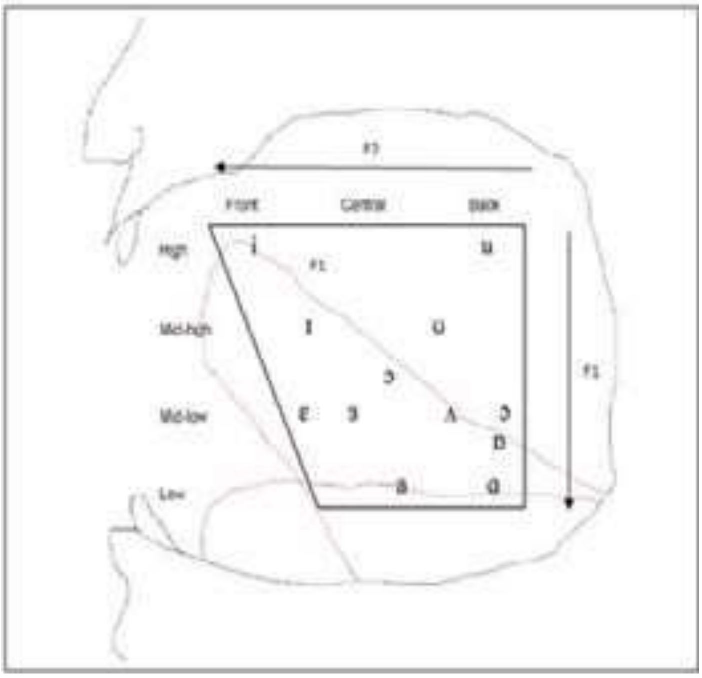

Figure 1 Vowel quadrilateral

Vowel quadrilaterals provide a useful schematic representation of the relative articulatory requirements and corresponding acoustic characteristics of vowels. The tip of the tongue (as shown here in outline) is raised to produce an /i/ vowel (as in 'bee') and lowered to produce an 'a' vowel (as in 'bat'). Perceptual information is conveyed by reference to the **Figure 1** and **Figure 2** arrows indicating the values of the first and second high energy frequency 'formant' bands in the speech spectrum which are the main distinguishing feature of each vowel. /i/ has a low first format and high second formant while /a/ has a comparatively high first formant and middle range second formant.

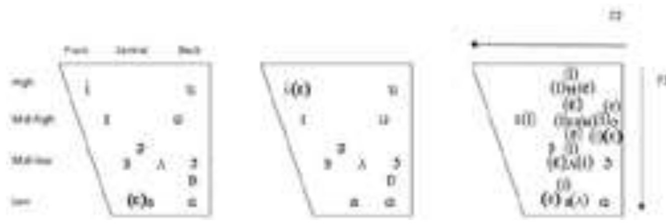

Figure 2 Different error patterns affecting /ɛ/. The first quadrilateral (a) shows /ɛ/ lowered to [a]. In the second quadrilateral (b) /ɛ/ is raised to [i]. The third quadrilateral (c) shows widespread backing of the entire front vowel series. In this case /ɛ/ is pronounced variably as a range of back vowel substitutes.

As shown graphically on the quadrilateral and represented by the co-ordinate labels high/low and front/back, the 'corner' or 'point' vowels /i, u, a, ɑ/ are the most mutually distinctive set. The mid vowel series are closer together and so require more articulatory precision on the part of the speaker to support the distinction for the listener. Some of these, the lax vowels /ɪ, ɛ, ʌ, ɒ, ʊ/ and /ə/ are also inherently shorter in duration than the other vowels, a factor which further undermines their articulatory and perceptual distinctiveness. It is, therefore, perhaps not surprising that these vowels appear to be most vulnerable to errored production in delayed/disordered systems [8]. Typically, they are substituted by one of the more peripheral vowels which are already secure within the child's system. For example, the mid low front vowel /ɛ/, which is repeatedly identified in the literature as problematic, is typically lowered to [a]. Some children though present with a raising error where /ɛ/ is pronounced as [i]. We can represent these two different error patterns on the vowel quadrilateral by placing the target vowel, in this example /ɛ/, in parentheses beside the vowel used in its place, in these examples [a], [i] (Figure 2).

The quadrilaterals in Figure 2a and 2b show systems in which /ɛ/ is subject to processes of vowel lowering and vowel raising. In each case process application is 100% resulting in a complete loss of contrast between /ɛ/ and /a/ in the first example and between /ɛ/ and /i/ in the second. The third quadrilateral shows the profile of a child who was one of a cohort of children assessed as part of the Central Scottish Vowel project [9]. At the time of assessment, he was 4 years 3 months and initially referred to the project with concerns raised about "vowel distortions". Taking a system wide approach to the data, revealed widespread vowel backing a systematic phonological process which affected all front vowels. Only /ɪ/ was additionally present in its own right. The error pattern was phonological in nature resulting in loss of vowel contrast rather than phonetic, ie there was no evidence of vowel distortions. The analysis also revealed significant variability in the range of the back vowels used in substitution and was of such an extent that there was no discernible pattern motivating the choice. This type of non-progressive variability indicates disordered development [3,5] and makes the child a priority for direct intervention since there is no evidence of spontaneous progressive change. Having established that the error patterns are phonological rather than phonetic we can also be confident in taking a contrastive phonological approach to intervention as opposed to an articulatory, motor based approach. We can also see immediately which specific contrasts should be targeted eg in this case /i/ versus /u/ (high front versus high back) or /i/ versus /ɛ/ (high front versus mid low front) or /i/ versus /ɛ/ versus /a/ (high front versus low mid front vs low central). Anecdotally it is interesting to note that following this approach, the child's entire system was established within a period of six months.

This child was also unusual in their treatment of the diphthongs /ai, au, ɔi/ which he consistently reduced to their first element. The process of diphthong reduction is a relatively common vowel error pattern [1,8]. However, in this case, the /i/ and /u/ off glide were replaced with a nasal consonant, yielding, for example, 'eyes' /aiz/, [amz]; 'butterfly' /bʌtəflai/, [bʌtəfan]; 'clouds' /klaudz/, 'boy' /bɔi/ [ban]; [klantz]; 'house' /haus/, [hans]. This interplay between consonants and vowels was even more marked in the case of another slightly older child (5; 2 years) from this cohort. This child also had a highly unusual profile in which the high corner vowels /i/ and /u/ were both essentially absent. Both vowels were pronounced as [ɪ]. However, the child maintained a consistent functional contrast between them by recruiting consonantal features to support the distinction – a palatal stop [ɟ] in the case of /i/ and a bilabial stop [b] in the case of /u/, thus "very funny, you see" was expressed as [vɛɹɪɟ fʌnɪɟ jɪb sɪɟ] ('verig funnig jib sig'). This pattern also applied in the case of the /i/ and /u/ off glides in diphthongs such as /ai/ and /au/, thus "moos from cows" was expressed as [mɪbz fəm kabz].

These children are particularly unusual in their use of consonants to support vowel contrasts. More common consonant vowel interactions include instances whereby vowel production is influenced by adjacent consonant context or where consonant production is influenced by adjacent vowel context. An example of consonant to vowel influence is provided by a third child from the cohort (aged 4;6 yrs). This child consistently lowered /ɛ/ to [a] in the context of a following [l] as in, for example, 'shell', /ʃɛl/, [ʃal]; 'telephone', /tɛlɪfon/, [talɪson]; 'melting' /mɛltɪŋ/ [maltɪŋ]. Elsewhere, they pronounced /ɛ/ as the diphthong [ai] as in, for example, 'pencil', /pɛnsɪl/, [painsɪl]; 'them', /đɛm/, [đaim]; 'red' /ɹɛd/, [ɹaid]; 'vest', /vɛst/, [vaist]; 'fence', /fɛns/, [psains].

A final example to illustrate vowel to consonant conditioning is provided by another child, (not part of the same cohort), Sam (pseudonym). At the time of assessment, Sam was aged 2;5 years and had a severely reduced consonant system. He showed a preference for [d] word initially and omitted many consonants word finally. Interestingly, while he presented with a disordered profile at this age, assessment at regular intervals revealed rapid progressive change within his system and a strong vowel to consonant influence. At 2;9 yrs, fricatives and affricates had started to appear word finally. However, these involved some non-English sounds and appeared highly variable, for example, 'dice', /dais/, [daiç]; 'knife' /naif/, [daiç]; 'bus', /bʌs/, [dʌx]; 'mouse', /maus/, [maux]; 'horse' /hɔs/, [hɔx]; 'torch' /tɔʧ/, [tɔx]; 'stripes', /stɹaips/, [taips]; 'clouds', /klaudz/, [taudz]. Non-system sounds (also referred to as phonetic distortions) are considered red flags for phonological disorder [2] as is non-progressive variability [7] and therefore might suggest a poor prognosis. Happily in this child's case, the variability proved to be systematic and phonetically principled.

Results

As shown in **Figure 3**, a clear pattern emerged when the target words were grouped according to the identity of the immediately preceding sound. The palatal fricative /ç/ occurred following the high front vowel /i/ which shares the same place of articulation, while the velar fricative /x/ made at the back of the mouth occurred following back vowels. The influence of the preceding vowel was blocked in cases where the target fricative was preceded by another consonant, eg /p/ and /d/ in the case of 'stripes' and 'clouds', allowing Sam to achieve near correct articulation – a distortion of the alveolar fricatives /s, z/, produced slightly further forward than is typical. In this child's case a detailed qualitative analysis looking at the system as a whole and taking into account potential conditioning factors revealed significant progressive change – a positive prognostic indicator which turned out to be justified, and avoided potential mis-diagnosis as ISD or CAS. It does though raise important questions relating to the interplay not only of consonants and vowels but also phonetics and phonology. It also begs the question of how clinically useful the delay vs disorder distinction is as a basis for prognosis and prioritising either individual cases or individual processes.

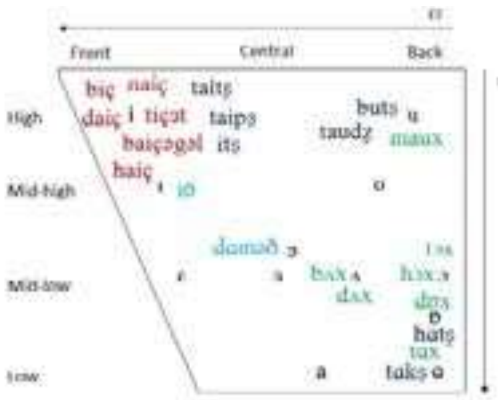

Figure 3 Example of vowel-to-consonant influencing effect

Discussion

Our current understanding of speech development has historically rested on the combined insights afforded by detailed single cases studies, often based on the description of development in the author's own children, case series grouped according to common features within the speech profile and larger cohort studies addressing issues such as language universals (ref). We have been able to apply this knowledge to the development of useful assessment tools which essentially capture the child's profile through listing the processes operating within the system at points of initial assessment and review and/or quantitative measures such as PCC scores. While there is a robust evidence base for the efficacy of this approach for most cases, we have raised the concern here that the approach may not be sufficiently fine grained to support children whose problems seem more severe and intractable. Specifically there is a risk of missing the systematic operation of linguistic or other constraints on natural phonological processes and atypical patterns which if known could materially affect not only the characterisation of the diagnosis/ profile in terms of delay and disorder but lead to inappropriate target selection and prognoses.

Ourargumenthasrestedonprovidingsomeexamplestohighlightnot only the range of factors which can influence speech development but also the complexity of their interplay in any one system. In making this case we have been conscious of underplaying the nature of this complexity. We have not included specific examples illustrating the impact of environmental considerations such as second or multi-language learning, socio emotional, medical and cognitive factors such as DLD or global issues (Please see Dodd, X and Crosbie for a more detailed discussion of these factors). Nor have we included the insights which instrumental research have brought to our understanding of speech patterns reflecting issues arising from co-articulation [5], covert contrasts [1] perceptual cue weighting [6] which are making a significant contribution to understanding the relationship between phonetics and phonology. The degree to which these all these factors are relevant will though depend on the individual circumstances of each child and for this reason we feel that there is much to be gained from encouraging a resurgence of interest in detailed documentation of the trajectory of speech development in individual children which is sensitive to the presence of all these factors.

Conclusion

There are currently few platforms for the publication of case studies of the detail required nor depositories which would allow comparison of trajectories and the distillation of common threads or patterns of interaction. The opportunity to collect clinical data over a period of development, by its very nature arrives unpredictably. We sense that there is some enthusiasm in the clinical field to better capture the further insights that this could bring, should there be a more easily accessible vehicle be available.

Acknowledgement

We would like to acknowledge Dr. Mark Samarneh of the Internal Medicine department for their assistance in the care of this patient.

Conflict of Interest

The author's declared that they have no conflict of interest.

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