Internal and external influences on child language productions

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1. Introduction*

Over the past three decades, statistical approaches have been successfully used to explain how young language learners discriminate the sounds of their mother tongue(s), perceive and acquire linguistic categories (e.g. phonemes), and eventually develop their mental lexicon. In brief, input statistics, i.e. the relative frequency of the linguistic units that children are exposed to (e.g. phones, syllable types), appear to provide excellent predictors in the areas of infant speech perception and processing. This research offers useful insight into both the nature of the linguistic input that infants attend to and how they sort out the evidence from that input (see Gerken 2002 for a recent overview).

Building on this success, a number of linguists have recently proposed statistical explanations for patterns of phonological *productions* that were traditionally accounted for through typological universals, representational complexity, grammatical constraints and constraint rankings, or lower-level perceptual and articulatory factors. For example, Levelt, Schiller and Levelt (1999/2000) have proposed, based on longitudinal data on the acquisition of Dutch, that the order of acquisition of syllable types (e.g. CV, CVC, CCV) can be predicted through the relative frequency of occurrence of these syllable types in the ambient language. Following a similar approach, Demuth and Johnson (2003) have proposed that a pattern of syllable truncation resulting in CV forms attested in a learner of French was triggered by the high frequency of the CV syllable type in this language.

However, important questions need to be addressed before one can conclude that statistical approaches, or any mono-dimensional approach based on a single source of explanation, truly offer strong predictions for developmental production patterns. For example, one must wonder whether input statistics, which are mediated through the perceptual system and computed at the cognitive level, can have such an impact on production, given that production, itself influenced by the nature of phonological representations,

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involves a relatively independent set of cognitive and physiological mechanisms, some of which presumably independent from statistical processing.

In this paper, I first argue that while statistics of the input may play a role in explaining some phenomena, they do not make particularly strong predictions in general, and, furthermore, simply cannot account for many of the patterns observed in early phonological productions. Using this as a stepping-stone, I then argue that the study of phonological development, similar to that of any complex system, requires a multi-dimensional approach that takes into consideration a relatively large number of factors. Such factors include perception-related representational issues, physiological and motoric aspects of speech articulation, influences coming from phonological or statistical properties of the target language and, finally, the child's grammar itself, which is constantly evolving throughout the acquisition period and, presumably, reacting or adapting itself to some of the limitations that are inherent to the child's immature speech production system. I conclude from this that any analysis based on a unique dimension, be it statistical, perceptual or articulatory, among many others, restricts our ability to explain the emergence of phonological patterning in child language. To illustrate this argument, I discuss a number of patterns that are well attested in the acquisition literature. I argue that explanations of these patterns require a consideration of various factors, some grammatical, some external to the grammar itself.

The paper is organized as follows. In section 2, I discuss the predictions made by statistical approaches to phonological development, using the results from Levelt et al. (1999/2000) for exemplification purposes. I then confront these predictions with those made by more traditional approaches based on structural complexity and language typology, in section 3. I introduce the approach favoured in this paper in section 4. In section 5, I discuss a series of examples that provide support for the view that the acquisition of phonology involves a complex system whose sub-components may interact in intricate ways. I conclude with a brief discussion in section 6.

2. Statistical approaches to phonological productions: an example

Statistical approaches, when used to account for production patterns, make three main predictions, listed in (1). All other things being equal, they predict that the most frequent units found in the ambient language should appear first in the child's speech. As opposed to this, the least frequent units should appear last. Finally, units of equivalent frequency are predicted to emerge during the same acquisition period (itself determined through relative frequency) but to display variation in their relative order of appearance.

(1) Statistical approaches to phonological development: predictions
 a. Frequent units: acquired early
 b. Infrequent units: acquired late
 c. Units with similar frequencies: variable orders of acquisition

A clear illustration of the predictions made by the statistical approach comes from Levelt et al. (1999/2000), who conducted a study of the acquisition of syllable types by twelve monolingual Dutch-learning children. Their main observations are schematized in (2). As we can see, all learners' first utterances were restricted to the four types of syllables that are the least complex (CV, CVC, V, VC). Following this, the learners took one of two different paths, defining groups A (nine children) and B (three children). During this second phase, the groups either acquired pre-vocalic clusters before post-vocalic ones (CCV > VCC) or vice versa (VCC > CCV). Finally, all learners acquired the more complex CCVCC syllable towards the end of the acquisition period.

(2) Acquisition of syllable types in Dutch (Levelt et al. 1999/2000)

Group A: CVCC > VCC > CCV > CCVC
↗ ↘
CV > CVC > V > VC CCVCC
↘ ↗
Group B: CCV > CCVC > CVCC > VCC

We can see in (3) that the four syllable types acquired early (in (2)) are also the most frequently occurring ones in Dutch. The following four types, which distinguish the two groups of learners in (2), display relatively similar frequencies of occurrence in the language. Finally, the last syllable type acquired by all children (CCVCC) is also the one that occurs with the lowest frequency in the language.

(3) Frequency of syllable types in Dutch (Levelt et al. 1999/2000)
 CV > CVC > VC > V > {CVCC ≈ CCVC ≈ CCV ≈ VCC} > CCVCC

The correlation between the relative frequency of syllable types in Dutch and their order of acquisition thus seems to provide support for Levelt et al.'s suggestion that the emergence of production patterns in child language can be predicted through input statistics. For example, both orders of appearance and the variability that we observe between groups A and B seem to correspond to the statistical facts observed. In the next section, however, I introduce an alternative perspective on these same data.

3. Statistical frequency or representational complexity?

In light of the above illustration, one could be tempted to extend the statistical approach to a larger set of phenomena observed in child language. For example, we could hypothesise that the development of syllable structure in a given language is essentially governed by input statistics. However, important issues remain to be addressed before we can jump to such a conclusion and favour the statistical approach over more traditional ones. Such approaches have indeed been successful at accounting for various phenomena in child language, for example the acquisition of multi-syllabic word shapes (and related truncation patterns), or that of syllable structure (e.g. Ferguson and Farwell 1975, Fikkert 1994, Demuth 1995, Freitas 1997, Pater 1997, Rose 2000).

As was noted in the preceding section, the rate of acquisition of a given structure may be correlated with its frequency of occurrence in the target language. In contrast to this, an approach based on representational complexity predicts that the phonologically simplest units (e.g. singleton onsets) should be acquired before more complex units (e.g. complex onsets). However, in the case at hand (as well as, presumably, in most of the literature on the development of syllable structure), both the frequency-based and the complexity-based approaches make essentially identical predictions, because of the fact that, as far as syllable types are concerned, the most frequent also tend to be the simplest ones. This is certainly the case in Dutch where we can see that the four syllable types that were acquired first by all children in (2) are the ones that are the most frequent in (3) and also those that arguably show no complexity in their internal constituents.[1] From this perspective, we are at best witnessing a tie between the two approaches under scrutiny.

However, a further look at the data that enable a distinction in learning paths between groups A and B in (2) actually raises doubts on the predictive power of the statistical approach. Indeed, if we consider only the acquisition order of the four syllable types that differentiate the two groups of learners, which are deemed to have equivalent frequency values in the target language, the statistical approach predicts a total of 24 possibilities (4! or 4x3x2=24). Yet only two of these 24 potential learning paths are attested in the data, despite the fact that twelve children were included in the study. While one may be tempted to blame the relatively small population investigated for this, it is important to note that the two sequences attested correspond exactly to those that an approach based on phonological complexity would predict. Indeed, as mentioned above, the learners from group A acquired post-vocalic consonant clusters before complex onsets ([CVCC > VCC] >> [CCV > CCVC]), while the learners from group B followed the opposite path and acquired complex onsets before post-vocalic clusters ([CCV > CCVC] >> [CVCC > VCC]). However, none of the potential paths intertwining pre-vocalic clusters with post-vocalic ones is attested.

(4) Unattested patterns
a. *CCV > CVCC > CCVC > VCC
b. *VCC > CCV > CVCC > CCVC
c. *…

Under the assumption that the representations of only two units have in fact been acquired (those for pre-vocalic versus post-vocalic clusters), but at different times, these data would suggest that a complexity-based approach enables both an accurate description of the data and an explanation for the non-attested acquisition paths. In contrast, the statistical approach overgenerates; it predicts many more learning paths than the ones attested.

As rightly pointed out by an anonymous reviewer, if only two units (representations for pre- and post-vocalic clusters) need to be acquired by the children, then the syllable types containing a single 'new' unit (e.g. CVCC and VCC, both of which show a post-vocalic cluster), should be acquired during the same developmental stage (see also Fikkert 1994 and Pan and Snyder 2003 for related discussions). While the data description provided by Levelt et al. (1999/2000) does not enable a complete verification of this prediction, it certainly points in its direction. Three data points are discussed by Levelt et al., namely after the first, third, and sixth recording sessions. I address each of these data points in the following paragraphs.

After the first recording session, while most (eight of the twelve) children systematically failed to produce pre- or post-vocalic clusters, child David had CVCC but not VCC, Catootje had CVCC, VCC, CCV but not CCVC, Enzo had CCV, CCVC, CVCC but not VCC, while Leon had the four syllable types with complex constituents, and only lacked CCVCC (the type also missing from all of the other children's productions). While these results are relatively mixed, the productions (or absence thereof) from the first eight children fully support the current hypothesis, since they display no unsystematic gaps. Also, given that the data were naturalistically recorded, the few apparently unsystematic gaps in the other four children's productions (e.g. the fact that both David and Enzo displayed CVCC but lacked VCC) may have occurred simply because the children did not attempt a particular syllable type. It is indeed likely that the sample available in the corpus underestimates the children's true phonological abilities, since the non-occurrence of a given syllable type may simply be an artefact of data sampling, especially for the rarely occurring types in the language. This conjecture is in fact supported by Levelt et al. (1999/2000:259), who show that VCC displays the second lowest frequency of all syllable types in Dutch, with a frequency value (1.03), which is only slightly above that of the CCVCC type (0.97). As opposed to this, the CVCC type shows a much higher relative frequency, at 5.51. Given these figures, we can hypothesize that both VCC and CCVCC syllable types were very seldom attempted by Dutch-learning children. This empirical issue suggests that an approach considering *attempted* syllables, in addition to the *attested* ones, should have been favoured (see Pan and Snyder 2003 for further discussion).

At the second data point, six children still had no complex constituents. One child, Tirza, had post-vocalic but no pre-vocalic clusters. Three children (David, Catootje and Leon) had both pre- and post-vocalic clusters but no CCVCC syllables, while child Eva had CVCC but not VCC. Finally, Enzo lacked VCC syllables but yet displayed CVCC and CCVCC. Similar to the first data point, the apparently unsystematic gaps again come from the rarely occurring (and presumably rarely attempted) VCC and CCVCC syllable types. Aside from this issue, the patterns from this second data point reveal generally systematic behaviours, if taken from a representational complexity perspective.

This latter observation is further reinforced by the third sample, where nine children (those from group A in (2)) show either post-vocalic or both pre- and post-vocalic clusters. Also, the rarely occurring CCVCC syllable type is only attested in the productions of children who independently displayed both clusters. Finally, of the three children from group B, two display pre-vocalic but no post-vocalic clusters, while the last one has the CCV but not the CCVC syllable type. This gap is the only one left unexplained by the complexity approach, but again without a means to verify whether that syllable type was even attempted by the child.

We can see from the above discussion that the vast majority of the observations lend support to an approach based on representational complexity, especially if one considers the possibility that the absence of a given cluster may be attributed to the fact it was not attempted. Put in the larger context of linguistic universals, the representational approach advocated here also finds independent motivation in factorial typology. As reported by Blevins (1995), word-initial and word-final consonant clusters pattern in independent ways across languages. We can see in (5) that genetically unrelated languages such as Finnish (Finno-Uguric) and Klamath (Plateau Penutian) allow for post-vocalic but not pre-vocalic consonant clusters. As opposed to these, languages such as Mazateco (Oto-Manguean) and Sedang (North Bahnaric) allow for pre-vocalic clusters but ban post-vocalic ones.

(5) CC clusters across languages (Blevins 1995)
a. Finnois, Klamath: CVCC but not *CCV
b. Mazateco, Sedang: CCV but not *CVCC

An analysis of the distribution of these clusters requires a formal distinction between the two cluster types (pre- and post-vocalic), such that complexity can be allowed in one independently of the other. Under the view that children's grammars are not fundamentally different from that of adults (e.g. Pinker 1984, Goad 2000, Inkelas and Rose 2008), children can acquire these clusters in various orders. Also, as predicted by an approach based on phonological complexity (as opposed to frequency), discontinuous learning paths such as the unattested ones in (4) should generally not occur.[2]

Finally, when we consider the issue of the predictive power of the statistical approach from a larger perspective, other questions arise as well. Child phonological patterns often have no direct correlates with the target languages being acquired (e.g. Bernhardt and Stemberger 1998). These emergent patterns include, among many others, consonant harmony (e.g. *gâteau* 'cake' [gato] → [tato]; Smith 1973, Goad 1997, Pater 1997, Rose 2000, dos Santos 2007), velar fronting (e.g. *go* → [do]; Chiat 1983, Stoel-Gammon 1996, Inkelas and Rose 2008), segmental substitutions (e.g.

vinger ‘finger’ [ˈvɪŋər] → [ˈsɪŋə]; Levelt 1994, Dunphy 2006), consonant cluster reductions (e.g. *brosse* ‘brush’ → [bɔs]; Fikkert 1994, Freitas 1997, Rose 2000), syllable truncations (e.g. *banana* → [bana]; Ferguson and Farwell 1975, Fikkert 1994, Pater 1997) and syllable reduplication (e.g. *encore* ‘again’ → [kɔkɔ]; Rose 2000). Because of their emerging nature, these processes cannot be predicted from the kind of statistical tendencies that would enable one to distinguish either languages or language learners from one another. While a certain relationship obviously exists between the manifestation of these processes and the sound patterns that compose the target language, this relationship typically relates to phonological or lower-level articulatory aspects of child language development, not statistics. Furthermore, the occurrence of a given process seems to be randomly distributed among the population of learners (e.g. Smit 1993). Despite some implicational relationships which have been argued for in the acquisition literature (e.g. Gierut and O’Connor 2002), no one can predict, given any population of learners, which children will or will not display a given process. Therefore, no direct relationship seemingly exists between emergent processes and the statistical properties of target languages. Note however that this claim does not rule out the possibility that specific statistics of the target language affect the actual manifestation of a process. As I will discuss further below, it is logical to think that a child may select a given segment or articulator as default because of its high frequency in the language.

When taken together, the observations above suggest that while statistics of the input should not be dismissed entirely, they should only be taken as one of several factors influencing phonological productions. In the next section, I discuss a number of additional factors, all of which should also be considered.

4. A more encompassing proposal

In order to provide satisfactory explanations for the patterns observed in child language, I argue that one needs to consider the two general types of factors listed in (6), which may either manifest themselves independently or interact with one another in more or less complex ways in child phonological productions.

(6) Factors influencing child language phonological productions
 a. Grammatical (internal)
 b. Non-grammatical (external)

Approaching child language through (6a) is by no means a novel idea. It has been pervasive in the acquisition literature since the 1970s (see Bernhardt and Stemberger 1998 for a comprehensive survey) and in works on learnability (e.g. Dresher and van der Hulst 1995). However, in contrast to most grammatical analyses proposed in the literature, I propose to bring the study of early productions into a broader perspective, one that extends beyond grammatical considerations and incorporates factors that relate to perception, physiology, articulation as well as statistics, to name a few (see also Inkelas and Rose 2008, and Fikkert and Levelt, in press).

In the next section, I discuss a series of phonological patterns observed in child language, some of which have been discussed extensively in the literature, often because of the analytical challenges they offer. I argue that each of these patterns lends support to the multi-dimensional approach advocated in this paper.

5. The multiple sources of phonological patterning in child language

I begin the discussion with the process of positional velar fronting, in 5.1, which highlights the interaction between grammatical and articulatory factors. In section 5.2, I discuss in turn a number of patterns that have been described as opaque chain shifts in the literature. I argue that these patterns are in fact opaque in appearance only. I propose that they are entirely predictable within a transparent grammatical system once we take into account the possible impacts of non-grammatical factors. Following a similar reasoning, I discuss, in section 5.3, a potential interaction between articulatory and statistically-induced pressures on the emergence of consonant harmony in a Dutch learner's productions. Finally, in 5.4, I briefly highlight observations that would be difficult to explain through lower-level (e.g. articulatory or perceptual) influences. All of these observations point to strong grammatical influences on child language development.

Because of space limitations, more comprehensive accounts than the ones sketched below would ideally be required as well as a consideration of issues such as variation, both within and across language learners. My aim is thus limited here to suggesting what I consider to be a sensible approach to the data, leaving the fine details of analysis for future work.

5.1. Grammatically-induced systematic mispronunciations

Velar fronting consists of the pronunciation of target velar consonants as coronal (e.g. ‘go’ → [do]). What is peculiar about this process is that when it does not apply to all target velars, it affects velars in prosodically strong positions (e.g. in word-initial position or in word-medial onsets of stressed syllables; see (7a)) without affecting velars in weak positions (e.g. medial onsets of unstressed syllables, codas; see (7b)) (e.g. Chiat 1983, Stoel-Gammon 1996, Inkelas and Rose 2008).

(7) Positional velar fronting (data from Inkelas and Rose 2008)

a. Prosodically strong onsets

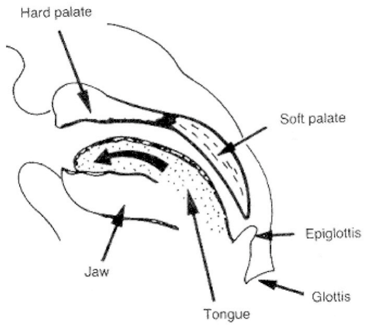
[ˈtʰʌp]	*‘cup’*	1;09.23
[ˈdoː]	‘go’	1;10.01
[əˈdɪn]	‘again’	1;10.25
[ˈhɛksəˌdɔn]	‘hexagon’	2;02.22

b. Prosodically weak onsets; codas

[ˈmɑŋki]	‘monkey’	1;08.10
[ˈbejgu]	‘bagel’	1;09.23
[bʊkʰ]	‘book’	1;07.22
[ˈpædjɔk]	‘padlock’	2;04.09

As discussed by Inkelas and Rose (2008), positional velar fronting is, on the face of it, theoretically unexpected, because positional neutralization in phonology generally occurs in prosodically weak, rather than strong, positions. Taking this issue as their starting point, Inkelas and Rose offer an explanation that incorporates both an articulatory and a grammatical component. The articulatory component of their explanation relates to the fact that young children are equipped with a vocal tract that is different in many respects from that of an adult, as illustrated in (8).

(8) Child vocal tract



Source: http://www.ling.upenn.edu/courses/Fall_2003/ling001/infant.gif

Inkelas and Rose emphasize the facts that (a) the hard palate of children is proportionally shorter than that of adults and (b) the tongue is proportionally larger and its mass is located in a more frontal area of the vocal tract. Adult vocal tract shapes and proportions are attained between six and ten years of age (e.g. Kent and Miolo 1995, Ménard 2002). In addition, young children do not possess the motor control abilities that adult speakers generally take for granted (e.g. Studdert-Kennedy and Goodell 1993).

These differences in vocal tract shape and control, Inkelas and Rose argue, are not without consequences for the analysis of early phonological productions. Certain sounds and sound combinations are inherently more difficult to produce for children than for adults. This is particularly evident in the acquisition of phonological contrasts that involve lingual articulations. For example, in languages like English in which we find a contrast between /s/ and /θ/, (e.g. *sick* /sɪk/ ~ *thick* /θɪk/), this contrast is often acquired late (e.g. Smit 1993, Bernhardt and Stemberger 1998). In addition, it is often the case that young children across languages show frontal lisp-like effects (e.g. /s/ → [θ]). The relative size and frontness of the tongue body, compounded by an imperfect control of motor abilities may both be at least partly responsible for the emergence of this phenomenon.

Coming back to positional velar fronting, Inkelas and Rose further argue that the positional nature of this phenomenon is not simply the result of articulatory pressures; it also has a significant grammatical component. It is well known that speech articulations are more emphasized in prosodically strong positions such as word-initial or stressed syllables (e.g. Fougeron and Keating 1996). It is also well known that children's developing grammars are particularly sensitive to the prosodic properties of their target language (e.g. Gerken 2002). It follows from this that children should be faithful to the strengthening of speech articulations in prosodically strong positions that they identify in the adult language. Building on these observations, Inkelas and Rose propose that the children who display positional velar fronting are in fact attempting to produce these stronger articulations in prosodically strong contexts. However, because of the articulatory factors listed above, the strengthening of their target velars results in an articulation that extends too far forward, into the coronal area of the hard palate, yielding the fronted velars on the surface. Inkelas and Rose's argument for the grammatical conditioning of positional velar fronting is further supported through another process observed in the same learner, that of positional lateral gliding, which takes place following the same strong/weak dichotomy of contexts as velar fronting even though the articulatory underpinnings of gliding are completely independent from those of fronting. In both cases, the child is cosmetically unfaithful to target segments but yet abides by strong requirements of the target grammar. This explanation has the advantage over previous analyses of reconciling the positional velar fronting facts with phonological theory, especially given that articulatory strengthening should occur in prosodically strong, not weak, positions.[3] In the context of the current argument, it also provides a clear case where non-grammatical, articulatory factors can interact with developing grammatical systems to yield the emergence of systematic patterning in child language.

In the next section, I address other patterns which may look suspicious from a grammatical perspective, as they suggest opacity effects in child grammars. I argue that once they are considered in their larger context, these apparently opaque processes can be explained in transparent ways.

5.2. Apparent chain shifts

A number of child phonological patterns that take the shape of so-called chain shifts have been considered cases of grammatical opacity in the literature, thereby posing theoretical and learnability problems (e.g. Smith 1973, Smolensky 1996, Bernhardt and Stemberger 1998, Hale and Reiss 1998, Dinnsen 2008). In line with Hale and Reiss' (1998) suggestion that (apparent) chain shifts are not a problem for theories that consider both competence *and* performance, I argue that these patterns can in fact be seen as entirely transparent if one incorporates factors pertaining to speech perception and/or articulation into the analysis.

Consider first the data in (9). As we can see in (9a), the child produces the target consonant /z/ as [d] in words like *puzzle*. This process of stopping, often observed in child language data (e.g. Bernhardt and Stemberger 1998), may by itself be related to articulatory or motor factors such as the ones listed in the preceding section. However, as we can see in (9b), target /d/ is itself pronounced as [g] in words like *puddle*.

(9) Chain shift (data from Amahl; Smith 1973)
  a. *puzzle* /pʌzl/ → [pʌdɫ̩] (/z/ → [d])
  b. *puddle* /pʌdl/ → [pʌgɫ̩] (/d/ → [g]; *[d])

If the child were grammatically able to produce [d] in *puzzle*, why is it that he could not produce this consonant in *puddle*. Schematically, if A→B, then why B→C (and not *B→B)? This apparent paradox, previously discussed by Macken (1980), reveals the importance of another non-grammatical factor, that of perception, which may have indirect impacts, through erroneous lexical representations, on the child's speech productions. As Macken argues, the child, influenced by the velarity of word-final [ɫ], perceived the /d/ preceding it in *puddle* as a velar consonant (/g/). Because of this faulty perception, he built a lexical representation for *puddle* with a word-medial /g/. The production in (9b) thus results from a non-grammatical, perceptual artefact which, itself, contributes to the emergence of a paradoxical production pattern. The paradox is only apparent, however; it is not inherent to the grammar itself.[4]

Another possibility for chain shifts emerges when both perceptual and articulatory factors conspire to yield phenomena that should be unexpected, at least from a strict grammatical perspective. An example of this, also from Smith (1973) is provided in (10) (see also Smolensky 1996 and Hale & Reiss 1998 for further discussion of this case). As we can see, /θ/ is realized as [f] (in (10a)), even though it is used as a substitute for target /s/ (in (10b)).

(10) Circular chain shift (data from Amahl; Smith 1973)
  a. /θ/ → [f] (*thick* /θɪk/ → [fɪk])
  b. /s/ → [θ] (*sick* /sɪk/ → [θɪk])

Again here, why cannot the child realize target /θ/ as such if [θ] is otherwise possible in output forms (from target /s/)? Consistent with the current approach, I argue that patterns such as the one in (10) should simply not be considered for grammatical analysis, because it arises from a conspiracy of independent factors, namely perception, which affects the building of lexical representations, and articulation, which yields surface artefacts in output forms. First, the realization of /θ/ as [f] can arise from a perceptual problem caused by the phonetic similarity between these two segments. Indeed, the contrast between these two sounds is often neutralized by both first and second language learners, who tend to realize both consonants as [f] (e.g. Levitt, Jusczyk, Murray and Carden 1987, Brannen 2002). This phenomenon is peculiar because it involves consonants with different places of articulation. However, since /f/ and /θ/ are acoustically extremely similar (e.g. Levitt et al. 1987), the merger is not surprising: if the contrast cannot be perceived by the learner, it cannot be represented at the lexical level and, consequently, cannot be reproduced in production. Coming back to the examples in (10), the child thus perceives /θ/ as [f] and, consequently, lexically encodes a target word such as *thick* with a word-initial /f/ (/fɪk/). This enables an account of the assimilation observed in (10a). Second, if the same child has not yet mastered the precise articulation required for the production of /s/, which is realized as [θ] for reasons such as the ones mentioned in section 5.1, we obtain the second element of the apparent chain shift in (10b).

The examples discussed thus far highlight ways in which phonetic considerations may affect the child's analysis of the ambient language, for example by imposing perceptually driven biases on lexical representations or articulatorily induced artefacts on speech production. Building on this argument, Hale and Reiss (1998) would further suggest, quite controversially, that examples such as this one basically discredit the study of child language phonology from a production perspective. I argue that Hale and Reiss are in fact making a move that is tantamount to throwing the baby out with the bath water. Contra Hale and Reiss, and in line with most of the researchers in the field of language development, I support the claim that the child's developing grammatical system plays a central role in the production patterns observed, with the implication that productions are worthy of investigation in our quest to unveil the grammatical underpinnings of child language development. This position is further substantiated in the next two sections, where I discuss examples of processes that reveal more abstract aspects of phonological (grammatical) processing.

5.3. Interaction between cognitive and articulatory factors

Despite the criticisms formulated against statistical approaches in section 3, I reiterate that the argument of this paper is not about rejecting statistical influences altogether, but rather to incorporate them into the larger picture of what factors can influence grammatical development. This is especially true in cases where a given unit (e.g. sound, syllable type) can be singled out as statistically prominent in the ambient language and thus selected by the learner's grammar as representing a default value. As discussed in section 3, if this default option correlates with articulatory simplicity, then there is no easy way to firmly conclude which factor (statistical or articulatory) is the determining one. However, if the default option from a statistical perspective does not correlate with articulatory simplicity, then we should be expecting children to display variation between the two alternatives. In this section, I discuss patterns of segmental substitution attested in the productions of Jarmo, a young learner of Dutch. We will see that when confronted with a sound class that he cannot produce, Jarmo opts for various production strategies, which themselves suggest a number of influences on his developing grammar.

As Dunphy (2006) reports, Jarmo displays difficulties with the production of labial continuants (e.g. /f, v, ʋ, w/) in onsets. However, instead of producing these consonants as stops, a strategy that would appear to represent the simplest solution, his two most prominent production patterns consist of either substituting labial continuants by coronals or debuccalizing these consonants through the removal of their supralaryngeal articulator. Stopping occurs but is only the third preferred strategy, as evidenced by the breakdown in (11).

(11) Realization of labial continuants in onsets (Dunphy 2006)

Attempted forms	229	
Target-like	44	19%
Coronal substitution	98	43%
Debuccalization	34	15%
Stopping	22	10%
Velar substitution	11	5%
Other	19	8%

The two main strategies, coronal substitution and consonant debuccalization, are exemplified in (12a) and (12b), respectively.

(12) Examples of substitution strategies for labial continuants

a. Coronal substitution	b. Debuccalization
vis [ˈvɪs] → [ˈsiʃ]	*visje* [ˈvɪʃə] → [ˈʔis͡jə]
fiets [ˈfits] → [ˈtɪt]	*willy* [ˈʋɪli] → [ˈhili]
vinger [ˈvɪŋər] → [ˈsɪŋə]	*fiets* [ˈfits] → [ˈʔiʃ]

In the face of these data, we must find out why the child favoured two strategies affecting the major place of articulation of the target consonants. It is also necessary to determine whether there is a formal relationship between coronals and laryngeals in the child's grammar, given that both of them act as favoured substitutes for target labial continuants.

First, the distribution of coronals in Dutch (as well as in many of the world's languages; see contributions to Paradis and Prunet 1991) provides support for the hypothesis that the child can analyze them as default (statistically unmarked) consonants in the language. Indeed, coronals account for 55% of all onset consonants and 65% of all coda consonants in spoken Dutch (van de Weijer 1999). In addition, from the perspective of syllable structure, coronals are the only consonants that can occupy appendix positions in Dutch (see, e.g. Fikkert 1994 and Booij 1999 for summaries of the research on syllable structure in Dutch). From both statistical and distributional perspectives, coronals can thus appear to the learner as having a special, privileged status. Second, laryngeals are considered to be the simplest consonants from an articulatory perspective by many phonologists and phoneticians (e.g. Clements 1985). Indeed, these consonants do not involve any articulation in the supralaryngeal region of the vocal tract. Both coronals and laryngeals thus offer the child good alternatives, which manifest themselves in output forms.

5.4. Grammatical influences

Finally, the argument presented above would not be complete without a discussion of influences on the child's productions that seem to be inherent to the grammatical system itself. Despite perceptual and articulatory effects such as the ones discussed in the preceding sections, several facts documented in the literature on phonological development strongly suggest the presence of general grammatical principles whose effects can be observed independently in language typology, as already discussed in section 3. For example, while various combinations of perceptual and articulatory factors should yield fairly extensive variation between learners, even within the same target language, it is generally noted that variation is in fact fairly restricted. Also, several works attribute some of the variability observed between learners to differences between individual rates of acquisition rather than actual discrepancies in grammatical analyses once the target phonological structure is mastered by the learners (e.g. Fikkert 1994, Levelt 1994, Freitas 1997, Goad and Rose 2004).

In addition, relationships between various levels of phonological representation, for example, the role of prosodic domains such as the stress foot, the syllable, or syllable sub-constituents in segmental patterning all point towards clear grammatical influences over child language productions (e.g. contributions to Goad and Rose 2003; see also section 5.1 above).

Note also that in the vast majority of the cases documented in the literature, the emerging properties of child language are grammatically similar to those of adult languages. There are also strong reasons to believe that apparent counter-examples to this generalization are in fact more cosmetic than reflecting truly unprincipled grammatical patterns (e.g. Inkelas and Rose 2008), in the sense that these counter-examples derive from non-grammatical factors such as those discussed in the above subsections. Indeed, we can generally account for sound patterns in child language using theories elaborated on the basis of adult languages. This in itself implies a strong correspondence between the formal properties of developing grammars and that of end-state (adult) systems. This correspondence in turn reveals a set of grammatical principles that should be considered in analyses of child language productions. In this regard, it is also important to highlight the fact that most of the analyses proposed in the literature on phonological development require a certain degree of abstraction, one that extends beyond perception- or articulation-related issues such as the ones noted in preceding sub-sections.

While more observations should be added to this brief survey, we can reasonably conclude that despite the fact that child language is subject to non-grammatical influences, its careful study reveals a great deal of systematic properties. In turn, these properties can be used to formally characterize the stages that the child proceeds through while acquiring his/her target grammar(s).

6. Discussion

In this paper, I have discussed phonological patterns that offer strong empirical arguments against any mono-dimensional approaches to phonological development, be they based solely on statistical, phonetic or grammatical considerations. I argued that an understanding of many developmental patterns of phonological production requires a multi-dimensional approach incorporating, among others, perceptual factors that can affect the elaboration of lexical representations, articulatory factors that can prevent the realization of certain sounds, as well as the phonological properties of the target language itself (e.g. phonological and phonetic inventories, distributions and statistics; prosodic properties). A consideration of these factors offers many advantages, including both the avoidance of unnecessary analytical issues imposed by true grammatical opacity and, crucially, the explanatory power of the more transparent analyses proposed.

As in all multi-factorial approaches, one of the main challenges lies in the determination of what factors are involved and of how these factors interact to yield the outcomes observed in the data. For example, one important issue that was left open in this paper concerns the fact that while statistics of the input seem to play a central role in infant speech perception, such statistics appear to be only one of the many factors underlying patterns observed in speech production. The relationship between perception and production thus remains one that warrants further research. In order to tackle this issue, we should favour strong empirical, cross-linguistic investigations within which all of the languages involved would be compared on the basis of their distinctive linguistic properties. By combining the results obtained through such investigations with those from research on speech perception and articulation by children, we should be in a better position to improve our understanding of phonological development, from the earliest months of life through the most advanced stages of attainment.

Notes

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1. One could argue that post-vocalic consonants in VC and CVC forms involve complexity at the level of the rhyme constituent. This position is however controversial; several authors have in fact noted asymmetrical behaviours in the development of word-final consonants and argued that these consonants cannot always be analyzed as true codas (rhymal dependents) in early phonologies and should considered as onsets of empty-headed syllables (e.g. Rose 2000, 2003, Barlow 2003, Goad and Brannen 2003).
2. Of course, one should not rule out the possibility that a regression in the acquisition of consonant clusters yields one of the patterns in (4). The presumption here is that such regressions are unlikely to occur, especially in typically developing children (e.g. Bernhardt and Stemberger 1998).
3. As correctly noted by an anonymous reviewer, it is not clear whether the child analyses the strong and weak velars as allophones or separate phonemes. This issue is however tangential to the analysis proposed.
4. An anonymous reviewer notes that there may be perceptual or articulatory factors involved in the pronunciation of /z/ as [d]. This point reinforces the argument of this paper about the need to entertain several potential factors in the analysis of child phonological data.

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