Towards a Typology of Word-initial Consonant Clusters: Evidence from the Acquisition of Greek

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Abstract
In this paper, I study the production of consonant clusters by Greek children and examine the consequences of the acquisition data for phonological theory, with particular emphasis on the word-initial position. Using a non-word repetition test, I tested the order of acquisition of word-initial and word-medial s+obstruent (sT), obstruent-obstruent (TT) and obstruent-sonorant (TR) clusters in 59 children. The results provide evidence against any analysis that assigns identical status to word-initial sT and word-initial TT, such as models of extrasyllabicity, and lend support to an alternative analysis of the beginning of the word, based on Lowenstamm's (1999) initial ON hypothesis and CVCV theory (Scheer 2004).

Keywords
consonant clusters, CVCV, extrasyllabicity, Greek, phonology, language acquisition

1 Introduction

First language acquisition data can provide us with considerable insight into the study of phonological representations. Of particular interest is the order in which children acquire various phonological structures, as acquisition has been shown to be influenced by markedness[1]. Specifically, children master the production of unmarked sounds or structures before marked ones (Demuth 1996; Gnanadesikan 1995; Jakobson 1968; Stites et al. 2004).

An area that would greatly benefit from acquisition data is that of word-initial consonant clusters. Though consonant clusters have been extensively studied by acquisitionists (Barlow 1997; Demuth and Kehoe 2006; Freitas

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[1] Other factors, such as phonotactic probability (Storkel 2001) and contiguity (van der Pas 2004) have also been argued to influence certain aspects of phonological acquisition. Also, (Revithiadou and Tzakosta 2004a; 2004b), working in the framework of Optimality Theory, have examined the role of positional faithfulness.

2003; Jongstra 2003; Kirk and Demuth 2005; Lleó and Prinz 1996; Pan 2005; Pan and Snyder 2004; Vanderweide 2005) the focus of the research on word-initial position has been on obstruent-sonorant clusters (TR) and s+consonant (sC) or s+obstruent (sT) clusters. Other word-initial clusters, such as obstruent-obstruent clusters (TT) have been largely ignored. These clusters (for example *ft, xt,* which are attested in Greek) are problematic for phonological theory as they do not respect the regular rising-sonority pattern associated with the beginning of a syllable[2], a fact which has led phonologists to assume that these clusters are extrasyllabic. Word-initial TT is generally assumed to have the same structure as sT clusters. The latter cluster type is problematic not only in phonological theory, but also in the study of language acquisition. Since the better-studied languages, such as English, do not allow word-initial TT clusters, studying the acquisition of TT clusters alongside sT clusters in a language such as Greek would provide us with a unique opportunity to better understand the behaviour of sT clusters. More generally, studying the acquisition of different clusters in different positions, for example word-initial clusters alongside their word-medial counterparts, can be considerably more insightful than studying the acquisition of a cluster type in isolation.

In this article, in order to examine the phonological representations of the clusters in question, I test the production of consonant clusters by children acquiring Greek as their first language.

I organize this study as follows: I first give a short overview on the word-initial clusters in question and their acquisition, and then discuss the process of data collection. I then present the general results of the investigation and proceed to the analysis, presenting issues that are problematic for the extrasyllabic theory. Finally, I introduce an alternative proposal for the analysis of the data based on Lowenstamm's (1999) initial ON hypothesis and CVCV theory (Scheer 2004).

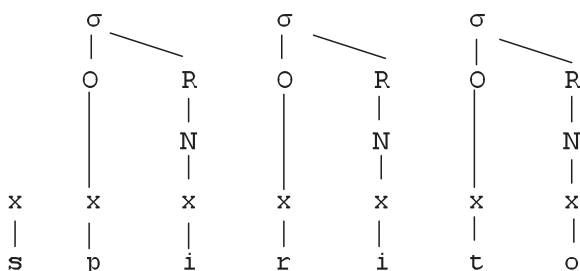## 2 Word-initial consonant clusters

2.1 Representations

Word-initial sT clusters do not respect the Sonority Sequencing Generalisation (SSG, Clements 1990), according to which sonority increases towards the

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[2] Greek also allows other clusters that do not follow the rising-sonority pattern word-initially, such as *mn*. However, in this study we focus on sT and TT clusters only.

syllable peak and decreases towards the edges. Initial sT breaks this generalisation, since the second member of the cluster has a lower (in the case of stops) or an equal (in the case of fricatives) sonority value when compared to the first member (*s*). This is the opposite of what the SSG dictates for onsets, namely that the second member of the cluster should be of higher sonority.

Faced with this inconsistency, a significant number of researchers have opted for a syllabification algorithm that leaves the *s* outside the onset: the *s* is extrasyllabic[3] (e.g. Halle and Vergnaud 1980, Levin 1985, Steriade 1982 amongst many others). An example of such a structure is given in (1) below.
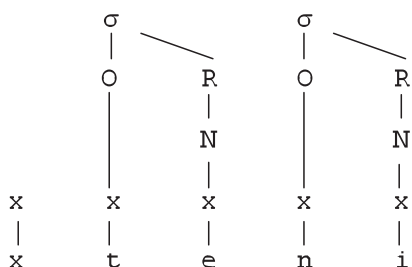
(1) sT extrasyllabicity: Italian *spírito* 'spirit'

```
        σ                σ                σ
        |  \             |  \             |  \
     O     R          O     R          O     R
     |     |          |     |          |     |
           N                N                N
           |                |                |
  x     x     x       x     x          x     x
  |     |     |       |     |          |     |
  s     p     i       r     i          t     o
```

Later in derivation the *s* may be linked to a constituent via some kind of adjunction rule[4] (for a review of different approaches to extrasyllabic segments, as well as an overview of arguments in support of extrasyllabicity the reader is referred to Vaux, 2009). The desired effect is thus attained: at the first stage, the SSG is not violated, since the *s* is not linked to the onset, while at the same time eventual integration to the syllabic structure is achieved.

The same extrasyllabic structure has been proposed for word-initial TT clusters (e.g. Rubach and Booij 1990, Steriade 1982). As these clusters, too, violate the SSG, an identical phonological analysis for both sT and TT, such as extrasyllabicity, seems to be a sensible move.
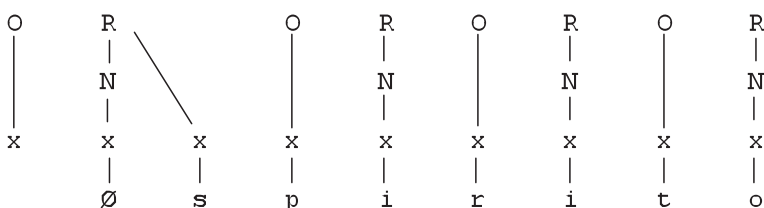
However, extrasyllabicity fails to capture an important point: that sT clusters are attested in languages that have no other SSG violating clusters. This type of evidence led Kaye (1992) to argue that sT clusters are unique because

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[3] Other attempts include analysis of sT as a contour-complex segment (Selkirk 1982, van de Weijer 1993, cf. Scobbie 1997) and the abandoning of the SSG as a universal principle (Cairns 1988) or the exclusion of obstruent clusters from the control of the SSG (Morelli 1999; 2003). See also Goad (in press) for an overview of different approaches to *s*-clusters.

[4] Alternatively, in constraint-based phonology, linking is achieved via the ranking of relevant constraints, see e.g. Green (2003).

(2)　TT extrasyllabicity: Greek *xténi* 'comb'

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              σ                    σ
              |                    |
         O    R              O     R
              |                    |
              N                    N
              |                    |
    x    x    x              x     x
    |    |    |              |     |
    x    t    e              n     i
```

of some special property of *s*. This property sets sT clusters apart from all oth-
ers, and is responsible for other peculiarities of sT (see, for example, the distri-
bution of the singular masculine definite article in Italian, Davis, 1990, Kaye,
1992). The nature of this property, Kaye claims, is not yet understood, but its
existence has to be recognized. In Government Phonology, the framework
developed in Kaye's paper, this property enables the *s* to 'magically' occupy a
word-initial coda position.

(3)　Word-initial coda: Italian *spirit*

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    O    R              O    R         O    R         O    R
         |                   |              |              |
         N                   N              N              N
         |                   |              |              |
    x    x    x         x    x         x    x         x    x
    |    |    |         |    |         |    |         |    |
    ø    s    p         i    r         i    t         o
```

Moreover, Kaye et al. (1990), suggest that (ancient) Greek word-initial *pt*/*kt*
clusters are of the same nature as sT. Such a suggestion contradicts the insight
of the special nature of *s*. However, the fact that neither sT nor TT can be
accommodated within the canonical syllabic structure led Kaye et al. (1990)
to suggest that the two have the same structure.

Some more theory-neutral evidence that initial sT and initial TT share the
same structure stems from the observation that the two clusters show identical
behaviour in languages that allow both cluster types (Seigneur-Froli, 2006;
Steriade, 1982). A well-known example is Attic Greek reduplication: perfect
tense forms of stems beginning with sT and TT follow the same pattern, in
contrast to verbs that begin with TR (examples in (4) after Seigneur-Froli,
2006, Steriade, 1982). The perfective forms of stems commencing with a

single consonant (including *s*) are formed by reduplication, through the addition of an initial syllable consisting of the first consonant followed by *e* (4a). In the case of stems commencing with TR clusters, reduplication also takes place (the initial syllable consists of the obstruent plus *e*) (4b). In contrast, stems commencing with TT do not trigger reduplication and the vowel *e* is simply added word-initially (4c). As for the perfective forms of stems starting with sT, these are formed in the same way as TT initial stems (4d).

(4)　　　　　Present　　　　　Perfective

    a. CV

        paideúoo　　　*pepaideuka*　　　'to bring up'
        lúoo　　　　　*leluka*　　　　　'to untie'
        saleúoo　　　　*sesaleumai*　　　'to rock'

    b. TR

        krínoo　　　　*kekrika*　　　　'to pick out'
        klínoo　　　　*keklika*　　　　'to make to bend'
        pléoo　　　　　*pepleuka*　　　　'to sail'

    c. TT

        ptáioo　　　　*éptaika*　　　　'to stumble'
        ktéinoo　　　　*éktona*　　　　'to kill'
        pʰtʰánoo　　　*épʰtʰaka*　　　'to come first'

    d. sT

        spáoo　　　　*éspaka*　　　　'to draw' (a sword)
        stélloo　　　　*éstalka*　　　　'to arrange'
        spʰálloo　　　*éspʰalka*　　　'to make to totter'

This pattern has led phonologists to conclude that word-initial sT and word-initial TT have the same structure (Seigneur-Froli, 2006; Steriade, 1982).

   (Modern) Greek does not exhibit reduplication or other phonological processes that would enable us to draw firm conclusions as to the relationship between the two cluster types. Tzakosta and Karra (2007) examine the representation of Greek clusters based on dialectal data. They argue for a modification of the sonority scale, proposing two scales, one for place and one for manner[5], against which clusters are rated for acceptability. Consonant clusters

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[5] For another proposal involving separation of place and manner in assessing the well-formedness of clusters see Morelli (1999; 2003).

are rated as 'perfect', 'acceptable' and 'non-acceptable' depending on the degree to which they satisfy the two scales. Unfortunately, while TT clusters feature in all three categories, sT clusters are absent from the proposed classification. Also, no distinction is attempted between word-initial and other positions.

Pagoni (1993; 1998) working in the framework of Government Phonology (Charette, 1990; Harris, 1994; Kaye et al., 1985; 1990) proposes an analysis of TT clusters that differs from that of sT clusters. She argues that while sT clusters constitute coda-onset sequences (see representation in example (3)), TT clusters consist of two onsets separated by an empty nucleus. For a detailed critique of Pagoni's analysis, the reader is referred to Seigneur-Froli (2006).

Finally, Seigneur-Froli (2006) examines word-initial position in Greek from a diachronic as well as a dialectal perspective. Based on evidence from the historical process of cluster dissimilation as well as on dialectal material involving initial cluster formation, Seigneur-Froli proposes an analysis for the beginning of the word in Greek which involves identical representations for sT and TT clusters. Note that, even though the main focus of Seigneur-Froli's research is word-initial TT, she provides evidence in favour of a theory (CVCV theory, Scheer, 2004) which does not provide different representations for the two cluster types (see, however, section 4.2 below).

To sum up, although the representations proposed for word-initial sT and TT clusters vary widely depending on the framework, the most widespread view is that the two clusters have the same structure. As extrasyllabicity is the most popular analysis, we adopt it as our starting point, bearing in mind that our focus is on the relationship between the two cluster types.

2.2 Order of acquisition

In first language acquisition, sT extrasyllabicity shows unusual behaviour. While several studies have shown that children start producing initial sT clusters after TR clusters (e.g. Chin, 1996, Smith, 1973), other studies (cf. Barlow, 1997, Gierut, 1999) found that some children produce initial sT clusters first.

The variation in the order of initial sT – initial TR acquisition has long puzzled researchers and there have been several proposals developed in order to tackle this problem. For example, it has been suggested that the explanation for these data lies in the possibility that some children acquire branching onset structures (TR) before extrasyllabicity, while others acquire extrasyllabic structures first (Fikkert, 1994). This assumes that extrasyllabicity and branching onsets (TR) are different, though equally marked, structures, and that the

order of acquisition is therefore subject to variation. A different suggestion holds that, in acquisition, extrasyllabic clusters (and more generally consonantal sequences) may be structured like affricates (Barlow, 1997; Lleó and Prinz, 1997). The relevant structure is shown below.

(5) sT as an affricate: Italian *spírito* 'spirit'
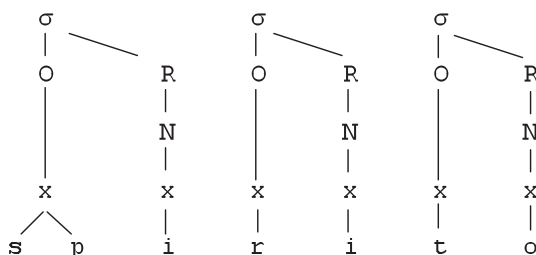
As seen in (5) sT clusters are represented as complex segments with a single timing slot. According to this approach, if a child does not structure sT like an affricate, s/he will acquire it after TR (i.e. as extrasyllabic, and therefore more marked). If, on the other hand, in a developing grammar, sT is structured like an affricate, it will be acquired before TR (on the assumption that complex segments are less marked than complex onsets). This optionality of structure, it is argued, can account for the variation observed the acquisition of initial sT – initial TR (Barlow, 1997). However, this approach does not seem to be particularly insightful, as it does not define what circumstances regulate whether a consonantal sequence will be structured as an affricate or as a cluster[6].

The acquisition of word-initial TT clusters has not received much attention. Even though researchers have shown an increasing interest in the acquisition of Greek phonology, the majority of the studies are concerned with the acquisition of stress patterns (Kappa, 2002b; Tzakosta, 2003; 2004) or of different sounds (Kappa, 2000; Nicolaidis et al., 2004; Tzakosta, 2001a) in specific positions (e.g. word-final consonants: Kappa, 2001). The studies that deal with consonant clusters are mostly concerned with what consonant children preserve when they simplify clusters (Kappa, 2002a; Tzakosta, 2001b). While these studies provide some data on children's production of TR and TT clusters, they are typically isolated examples. There is some evidence regarding

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[6] See also Scobbie (1997) for a conceptually motivated criticism of the contour segment analysis.

the acquisition of TR clusters as compared to e.g. other word-medial clusters, but word-initial TT clusters have largely been ignored (see, e.g. Kula and Tzakosta, 2002).

Preliminary results of a recent study by Tzakosta and Vis (2009a; 2009b; 2009c) indicate that Greek consonant clusters may show different behaviour in adult and child language. Tzakosta and Vis conducted an experiment in which children were asked to break up consonantal strings by inserting a vowel "wherever they considered it convenient" (Tzakosta and Vis, 2009a). An additional method used by the authors (Tzakosta and Vis, 2009b) was an investigation of children's cluster simplification patterns based on naturalistic developmental data. However, no robust conclusions can be drawn from this study yet, as the results have not undergone statistical analysis.

An analysis that assigns the same structure to word-initial sT and TT clusters, such as extrasyllabicity, predicts that their acquisition will follow the same pattern (under the assumption that structure determines acquisition order). Given that initial sT exhibits variation in the order of acquisition when compared to initial TR (in previously tested languages), the same variation will be expected in TT versus TR acquisition. Specifically, TT is expected to be acquired before or after TR following the reasoning below: if TT is extrasyllabic like sT, and if sT is acquired before or after TR, then TT will also be acquired before or after TR. Moreover, word-initial sT and TT are expected to be acquired at roughly the same time if they share the same (extrasyllabic) structure. Note that these predictions are not dependant on a specific view of extrasyllabicity; they follow as necessary consequences of any analysis that assigns the same structure to the two cluster types (always under the assumption that structure determines acquisition order). Moreover, assuming that the structure of word-medial sT and word-medial TT are the same, whatever the acquisitional relationship between initial and medial sT (i.e. whichever is acquired first), the same relationship should hold between initial and medial TT. Word-initial and word-medial TR, on the other hand, are expected to show no difference, since they involve the same structure (namely complex onset).

3 The experiment

3.1 Goal

The purpose of this experiment is to test Greek children's production of consonant clusters. Different clusters in different positions were tested and the

results compared. Specifically, sT, TT and TR clusters were tested in word-initial and word-medial position. All clusters were followed by a stressed vowel.

The cluster pairs we are interested in are the following:

(6)   #sT versus #TR
       #TT versus #TR
       #sT versus #TT
       #sT versus -sT
       #TR versus -TR
       #TT versus -TT   gloss: # word-initial
                                                - word-medial

3.2 Participants

Fifty-nine monolingual Greek children were tested (21 boys and 38 girls). The age range was from 2;03 to 5;00[7], mean age 3;08. The children were tested in four nurseries in Crete (three in Rethymno and one in Iraklio) and, in the case of one child only, in a relative's house.

The selection of the children followed developmental and linguistic criteria. All fifty-nine children participating in this study were reported by staff as being healthy, with no background of cognitive, behavioural, hearing or physical impairment. Moreover, all children were raised in a monolingual Greek environment, had typical linguistic development and were able to produce at least some consonant clusters.

3.3 Method

A non-word repetition task was used in this study. Children were encouraged to repeat novel, made-up words that had the desired structures. The task was chosen due to its effectiveness in producing a large amount of relevant data in a short period of time, compared to spontaneous production. Also, using non-words allowed us to avoid familiarity effects and to control the phonological environment of the clusters across conditions.

A number of measures were taken to ensure the naturalness of the task. Firstly, the words were paired with pictures of novel animals, so that the words would have a referent; I thus made sure that the task would be a linguistic one

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[7] Participants were not arranged in age groups. For the method of analysis followed see section 4.1.

(rather than a general non-linguistic sound-production task). Secondly, the children did not hear the stimuli from a recording, but from a person (the experimenter), in an attempt to provide a close match to everyday life situations. Later evaluation of the spoken stimuli words showed consistent use of appropriate segmental content and stress. Thirdly, the task was presented to the children as a game in which they were taking active part, and not as a request to repeat words (see procedure, section 3.5).

As a result of the above measures, children received the task as a natural interaction of a linguistic nature. Apart from the reassuring fact that children were enjoying the 'game' and some were asking for more, they were also making comments characteristic of natural interactions, that could have taken place in their classroom, and not just in an artificial experimental environment; for example: 'Will my sister meet these animals, too?' (Argiro 4;01). Moreover, a purely linguistic function that a number of children performed on the non-words spontaneously during testing was diminutive formation. For example, an animal called *kixró* was called *kixráki* by the child.

(7)　　*to*　　　　*mikró*　　　*kixráki*
　　　　the.N.SG　　little.N.SG　kixro.N.SG.DIM
　　　　'the little kixro'

This involved classifying the word as a neuter singular noun by the inflectional ending *-o,* removing the ending and adding the diminutive suffix *-áki* to the stem of the noun, in the regular way of diminutive formation for neuter nouns in Greek. This was a linguistic operation that could only be carried out if the child was involved in a linguistic task.

3.4 Materials

The experiment consisted of six conditions: three conditions contained words with sT, TR and TT clusters in word-initial position, and three conditions involved words with the same clusters in word-medial position. Five consonant clusters were tested in each condition. Care was taken to ensure that all major places of articulation allowed in Greek stops were used in all conditions, and that the number of individual consonants in each of the three conditions was roughly the same (six for sT and TT, seven for TR). The following combinations of consonants were tested:

(8)　sT:　　*sp, st, sk, sf, sx*
　　　TR:　　*tr, kl, fl, xr, vr*
　　　TT:　　*ft, xt, vð, γð, vγ*

The phonotactics of Greek were respected in the construction of the non-words. The words were possible nouns, feminine (with inflectional ending *-a),* neuter (inflectional ending *-o*) or either feminine or neuter (inflectional ending *-i*). Masculine nouns were avoided as they involve (in the nominative inflectional suffix) a word-final consonant (*-s*), which would increase the structural complexity of these trials. All words were bisyllabic, with a voiceless stop (*p, t* or *k*) as an onset for the non target syllable. There were five stimuli in each condition (by six conditions, thirty stimuli total). The stimuli used in the word-initial conditions were the following:

(9) sT: *spóki[8], stípo, skápi, sfíto, sxíka*
     TR: *tríka, klíto[9], flápi, xróki, vrípo*
     TT: *ftípo, xtíka, vðíto, ɣðóki, vɣápi*

The stimuli for the word-medial conditions were formed by reversing the syllable order:

(10) sT: *kispó, postí, piská, tosfí, kasxí*
      TR: *katrí, toklí, piflá, kixró, povrí*
      TT: *poftí, kaxtí, tovðí, kiɣðó, pivɣá*

For uniformity, the target cluster always preceded the stressed vowel, creating pairs such as *spóki – kispó.* Both members of these pairs are well-formed in Greek, which is characterised by a lexical accent system, restricted by the trisyllabic window (i.e. stress must fall in one of the last three syllables of the word)[10].

3.5 Procedure

After spending some time with the children in the classroom, thus making sure that the experimenter would become familiar to the children, each of the

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[8] Notice that *k* in Greek (and all the other velar consonants) becomes palatal before a front vowel. For example, *spóki* would be pronounced [*spóci*]. In Cretan dialects, the velar might undergo even further fronting (Newton, 1972). Indeed, all children exhibited some degree of fronting, the extent of which depended on the child's background. However, that does not affect our experiment in any crucial way. The stimulus producer's dialect has moderate fronting, typical of Cretan urban areas.

[9] One of the nurseries was in an area (Iraklio) where, in the local dialect, *l* tends to be palatalised before *i*. For example, *toklí* → [*tokʎí*]. Indeed, some children exhibited *l* palatalisation.

[10] For analyses of the Greek stress system see Arvaniti (1991), Drachman and Malikouti-Drachman (1999), Malikouti-Drachman (1989), Philippaki-Warburton (1976), Ralli (1988), Revithiadou (1999). For the acquisition of stress in Greek see (Tzakosta, 2003; 2004).

selected children was tested individually in a separate room. Each session lasted about half an hour.

The test items were arranged[11] in three different orders[12] so as to avoid sequence effects, and each of these orders was followed for one third of the children tested. Test items were preceded by four warm-up items which did not contain any clusters.

Pictures of novel animals were hidden in a number of places and the child was invited to retrieve them and 'free' them by calling each animal with their name. The hiding places included a Russian doll representing a wizard that had eaten the animals, a fairy's dress where the animals were sleeping, a box with a small opening, through which only the child's hand could go, pages of a book where the animals got lost, the belly of a smaller Russian doll representing a girl, where they went to keep warm, and, finally, a pair of trousers that the child was invited to empty so the experimenter could put them on. Designing the session in a way that involves an active task ensured that children's interest was kept throughout the experimental session, and by including various different activities, I made sure that the children's attention was constantly renewed and sessions were enjoyable for both the children and the experimenter.

If, after two attempts, the child was not replying, or the child's reply was obscured by background noise, we would move on to the next animal/word, and the word would be added to the end of the list as the name of some other animal. During the session, there were spontaneous conversations between the child and the experimenter. From these conversations (all DAT-recorded) information on the child's production of singletons was also extracted.

3.6 Transcription and coding

Transcription of children's responses was performed by the experimenter. Ten percent of the data were cross-checked by a second transcriber, who is a Greek native speaker and is well-trained in phonetic transcription. In particular, one-tenth of the responses of each child were independently transcribed. The consistency rate between the two transcriptions, focusing on the cluster data, was 96%.

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[11] Mixed with items for other tasks: a series of different tasks were administered to the children during these sessions (see Sanoudaki, 2009).

[12] Each of the three orders was created in the following manner: items were arranged in a random order, and then sequences consisting of three or more items belonging to the same condition were broken up.

Responses were coded as either correct or incorrect, taking into account only changes to the consonant cluster. Changes to any other consonant, vowel or stress were ignored. Vowels were seldom changed, and neither was the stress pattern[13]. Moreover, during the analysis of the recordings any consistent substitutions in the child's speech (in single consonant production) were noted. One such substitution was that of *l* for *r* (11).

(11)   *l* for *r* substitution (Emanouela 4;11,21)

    a. Single consonant production
      oréa → oléa 'pretty'N.PL
      xorái → xolái 'fit'3ʀᴅ SG

    b. Cluster production
      kartí → kaltí
      kixró → kixló

Responses that involved any such substitutions were coded as correct.

In the following section (4.1), experimental results are presented, while their contribution to the debate on phonological representations is discussed in section 4.2.

4 Results and discussion

4.1 Results

Figure 1 below contains the percentage of correct responses for each of the clusters in word-initial and word-medial position. Percentages were calculated on the basis of conflated raw figures.

Prima facie, one might conclude that only word-initial TT is different. However, this raw percentage measure can be misleading since this result could be achieved in a number of different ways. For example, a high percentage of correct responses for a particular cluster could be the result of either very high accuracy by few participants or mediocre response accuracy spread over many participants. As a result, this method is not a reliable measure of acquisition order. This problem is potentially enhanced because of the long age range of our participants, but it is also present in studies with narrower age range (see Kirk and Demuth, 2005). A more informative way of analysing

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[13] Coding was also performed using a set of alternative criteria, whereby any responses that involved a cluster belonging to the same category (sT, TT or TR) as the target cluster were coded as correct, even if the cluster was not the target one. The reason for implementing this coding criterion is that such responses may be taken as an indication that the child had mastered the relevant structure, even if s/he was unable to produce the segmental content of the specific cluster. The use of these criteria did not alter the findings (for more details see Sanoudaki, 2007).
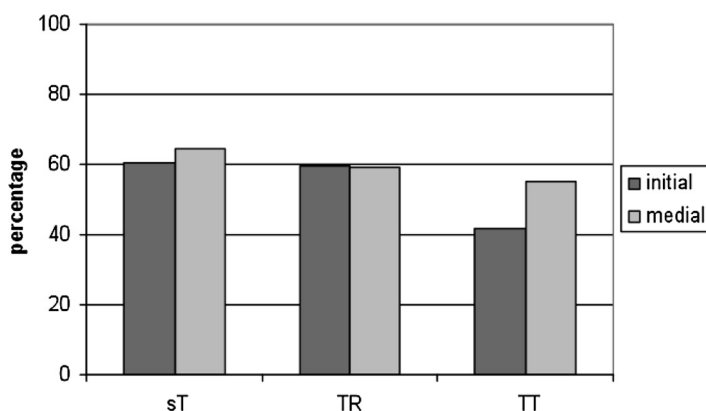
Figure 1. Percentage of correct responses for sT, TR and TT clusters in word-initial and word-medial position for all children combined.

data is to identify the number of correct responses for each member of a given cluster pair *for each child*. These data can then be used to determine the member of each pair that is produced more accurately by each child, and ultimately by children as a group. By analysing cluster pairs within the level of the individual participant first, we can examine the relative order of acquisition for each cluster pair irrespective of the age of the participants[14]. Note that this method of analysis is specific to our research question – i.e. the relative order of acquisition of cluster pairs – and might not be suited to all types of acquisition research, as it provides no information on the age of acquisition. At the same time, it is superior – at least for our purposes – to the traditionally used raw percentage measure, as it recognises the interdependence of responses coming from the same participant.

A visual presentation of the above method allows us to look at the overall results in conjunction with the results of each individual child. Table 1 below shows the number of correct responses for each child for word-initial sT versus word-initial TR. The vertical dimension represents the number of correct responses in the initial sT condition (from zero to five, which is the maximum number of correct responses), while the horizontal dimension corresponds to the number of correct responses in the initial TR condition (again from zero to five). Each tally mark in the table cells represents a child (total 59 children). One can therefore read out of the table the number of correct responses each

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[14] This approach is compatible with the practice of arranging children into age groups, and a combination of the two could potentially provide us with more in depth information. However, for such a combination to be possible, a larger number of participants would be required.

child gave in the two conditions. For example, nine children (in the first row) gave no correct responses in the sT condition. Of these children, four (in the first cell starting from the left hand side) gave no correct responses in the TR position either; two (in the second cell) gave one correct response; two (third cell) gave two correct responses and so on. Children are divided into two groups, represented by the two sectors that are divided by the diagonal: the top right sector contains children that performed better at TR, while the bottom left sector consists of children that performed better at sT. Children that fall on the diagonal performed the same in both conditions.

Table 1. Number of correct responses for # sT and #TR for each child

		#TR					
		0	1	2	3	4	5
#sT	0	////	//	//		/	
	1	//			//	/	
	2	/		//		/	
	3	/	/	/	//	///	/
	4	/	/	///	////	////	////// ///
	5			//	///	////	

A preliminary visual examination of the table suggests that the top right and the bottom left sectors are equally populated. A one-variable chi-square test that was carried out to test the difference between the two sectors had a χ^2 value of 0.095, with an associated probability value of p=0.758, DF=1. The test found no statistically significant difference between the two sectors. Moreover, the tally marks representing the children are scattered all over the table, showing that there is wide variation in performance. This includes children that performed almost adult-like at initial sT but poorly at initial TR, and vice-versa, as well as children that were equally advanced in the two cluster types. Some examples of children's responses, characteristic of the diversity, are given below. Kostantinos (a) performed very poorly at initial sT and very well at initial TR, while Fanouris (b) showed the opposite pattern. Aglaia (c) had roughly the same performance for the two cluster types, being only slightly better at initial sT (3 correct responses out of 5 as opposed to 2 out of 5 for initial TR).

(12) a. Kostantinos (2;11,17)

       #sT: 1 out of 5 target   #TR: 4 out of 5 target
       skápi → θkápi   *klíto → klíto*
       spóki → póki   *vrípo → vrípo*
       stípo → θípo   *xróki → xróki*
       sfíto → fíto   *tríka → tríka*
       sxíka→ ɕíɕka   *flápi → xlápi*

    b. Fanouris (3;04,15)

       #sT: 4 out of 5 target   #TR: 1 out of 5 target
       spóki → spóxi   *flápi → fla*
       stípo → stípo   *klíto → plíto*
       skápi → skápi   *vrípo → lípo*
       sfíto → sfíto   *xróki → lóki*
       sxíka → xíka   *tríka → tíka*

    c. Aglaia (3;03)

       #sT: 3 out of 5 target   #TR: 2 out of 5 target
       skápi → skápi   *klíto → klíto*
       spóki → spóki   *flápi → flápi*
       stípo → stípo   *vrípo → ptípo*
       sfíto → fíto   *xróki → kóki*
       sxíka → xíka   *tríka → tíka*

The table containing the number of correct responses for each child for initial TT versus initial TR is shown below, in table 2.

Table 2. Number of correct responses for #TT and #TR for each child

#TT \ #TR	0	1	2	3	4	5
0	//////// (diag)	//	/	//	/	/
1		X (diag)	////	/	//	//
2	/		X/ (diag)	//	///	/
3			/	X (diag)	///	////
4		/		///	X/// (diag)	///
5				/	/	X/ (diag)

The vertical dimension represents the number of correct responses in the initial TT condition (from zero to five), while the horizontal dimension shows the number of correct responses in the initial TR condition (again from zero to five). A visual examination of the table shows that the top right sector, corresponding to children that performed better at initial TR, is much more populated than the bottom left sector, which includes children that performed better at initial TT. The difference is statistically significant (χ^2=14.400, p<0.001, DF=1). Several children performed well at initial TR and poorly at initial TT, while the reverse pattern was uncommon[15]. In (13) I give some examples of individual children's performance. Kostantinos (13a) and Agelos (13b) performed very well at initial TR and poorly at initial TT. Zoi (13c) performed better than the two previous children at initial TT and adult-like at initial TR.

(13)   a. Kostantinos (2;11,17)

#TR: 4 out of 5 target	#TT: 1 out of 5 target
tríka → tríka	*ftípo → ftípo*
klíto → klíto	*vðíto → víto*
xróki → xróki	*ɣðóki → ðóki*
vrípo → vrípo	*vɣápi → ɣápi*
flápi → xlápi	*xtíka → tíxa*

　　b. Agelos (3;04,12)

#TR: 5 out of 5 target	#TT: 0 out of 5 target
tríka → tríka	*xtíka → ftíka*
klíto → klíto	*ftípo → stípo*
xróki → xróki	*vðíto → víto*
vrípo → vrípo	*ɣðóki → xróki*
flápi → flápi	*vɣápi → ɣápi*

　　c. Zoi (4;02,17)

#TR: 5 out of 5 target	#TT: 3 out of 5 target
tríka → tríka	*vɣápi → vɣápi*
klíto → klíto	*xtíka → xtíka*
xróki → xróki	*ɣðóki → ɣðóki*
vrípo → vrípo	*vðíto → ðíto*
flápi → flápi	*ftípo → xtípo*

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[15] In the cases of children that performed better at TT, the difference between TT and TR is small: specifically, there were only cases of one response difference (3-2, 4-3, 5-4), two responses difference (2-0, 5-3) and one case of three responses difference (4-1) (see table 2).

The table showing the number of correct responses for each child for initial sT and initial TT is given below, in table 3.

Table 3. Number of correct responses for #sT and #TT for each child

		#sT					
		0	1	2	3	4	5
#TT	0	///// //	///	/	//	//	
	1	//	✕	/	/	////	
	2		/	✕ //	///	///	
	3				✕	///// /	///
	4				//	✕ //// //	//
	5					/	✕ ///

More children performed better at sT than at TT (χ^2=16.9, DF=1, p=0.001). The top right sector is much more populated than the bottom left one. There is a large number of children that performed well at sT and poorly at TT, while few children performed better at TT than at sT[16]. Examples of individual children's performance are given below. Agelos (14a) and Maro (14b) performed very well at sT and very poorly at TT. Zoi's (14c) performance at TT was better than that of the two previous children, and for sT her performance was adult-like.

(14)   a. Agelos (3;04,12)

        #sT: 4 out of 5 target   #TT: 0 out of 5 target
        skápi → skápi   *xtíka → ftíka*
        spóki → spóki   *ftípo → stípo*
        stípo → stípo   *vðíto → víto*
        sfíto → sfíto   *ɣðóki → xróki*
        sxíka → skíka   *vɣápi → ɣápi*

    b. Maro (3;09,23)

        #sT: 4 out of 5 target   #TT: 1 out of 5 target
        spóki → spóki   *ftípo → ftípo*

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[16] In the cases of children that performed better at TT, the difference between TT and sT is consistently small: specifically, there were only cases of one response difference (1-0, 2-1, 4-3, 5-4) (see table 3).

stípo → *stípo*	*xtíka* → *tíka*
skápi → *skápi*	*vðíto* → *ðíto*
sxíka → *sxíka*	*ɣðóki* → *ðióki*
sfíto → *físto*	*vɣápi* → *vgápi*

   c. Zoi (4;02,17)

#sT: 5 out of 5 target	#TT: 3 out of 5 target
spóki → *spóki*	*vɣápi* → *vɣápi*
stípo → *stípo*	*xtíka* → *xtíka*
skápi → *skápi*	*ɣðóki* → *ɣðóki*
sxíka → *sxíka*	*vðíto* → *ðíto*
sfíto → *sfíto*	*ftípo* → *xtípo*

Having examined the results in the word-initial conditions, I now compare the results in the word-initial position with those in the word-medial position, starting with sT clusters.

In Table 4, which contains the number of correct responses for initial and medial sT for each child, no statistically significant difference is found between the two sectors (χ^2=0.714, p=0.398, DF=1). Some examples of individual children's performance are listed in (15a-c) below. Emanouela (15a) performed adult-like in both conditions, while Epistimi (15b) did not give any correct responses in either condition. Finally, Maraki's performance (15c) was between that of the two previous children, with two correct responses (out of five trials) in each condition.

Table 4. Number of correct responses for #sT and -sT for each child

#sT \ -sT	0	1	2	3	4	5
0	/////	/	/		/	
1	//		/	/	/	
2				/	//	
3			/	//	/////	
4			/	////////	///////	/////
5					//	/////

(15) a. Emanouela (4;11,21)

#sT: 5 out of 5 target	-sT: 5 out of 5 target
skápi → skápi	*piská → piská*
spóki → spóki	*kispó → kispó*
stípo → stípo	*postí → postí*
sfíto → sfíto	*tosfí → tosfí*
sxíka → sxíka	*kasxí → kasxí*

b. Epistimi (2;03,08)

#sT: 0 out of 5 target	-sT: 0 out of 5 target
spóki → póki	*piská → pijká*
stípo → sípo	*kispó → kipsó*
skápi → kápi	*postí → kutí*
sxíka → síka	*tosfí → tofí*
sfíto → pʰípo	*kasxí → kakí*

c. Maraki (3;05,03)

#sT: 2 out of 5 target	-sT: 2 out of 5 target
spóki → spóki	*piská → piská*
skápi → skápi	*postí → postí*
stípo → típo	*kispó → kipó*
sxíka → síka	*tosfí → sofí*
sfíto → títo	*kasxí → kaskí*

In table 5, the top right and the bottom left sector (divided by the diagonal line), corresponding to children that performed better at initial TR and medial TR respectively, are equally populated ($\chi^2=0.111$, p=0.739, DF=1).

Table 5. Number of correct responses for #TR and –TR for each child

-TR \ #TR	0	1	2	3	4	5
0	⧄/////					
1	//	⧄///		//		/
2	/		⧄/	///	/	/
3			//	⧄/	/////	/
4	/		///	//	⧄////	/////
5			/	//	///	⧄/////

There is a concentration of tally marks around the diagonal, indicating that children tended to perform equally well in both conditions. In (16) below, I give some examples of children's performance, illustrating this tendency. Stavros (16a) performed adult-like in both conditions, while Lena (16b) performed poorly in both conditions. Finally, Mario's performance (16c) was better than Lena's, but the child was still having problems with TR clusters in both positions.

(16)   a. Stavros (3;11,24)

-TR: 5 out of 5 target	#TR: 5 out of 5 target
katrí → *katrí*	*tríka* → *tríka*
toklí → *toklí*	*klíto* → *klíto*
piflá → *piflá*	*flápi* → *flápi*
kixró → *kixró*	*xróki* → *xróki*
povrí → *povrí*	*vrípo* → *vrípo*

   b. Lena (2;10,28)

-TR: 1 out of 5 target	#TR: 0 out of 5 target
toklí → *toklí*	*tríka* → *tíka*
katrí → *katí*	*klíto* → *cíto*
piflá → *piçfá*	*flápi* → *fápi*
kixró → *kixó*	*xróki* → *xóki*
povrí → *poví*	*vrípo* → *vípo*

   c. Mario (3;03,01)

-TR: 3 out of 5 target	#TR: 2 out of 5 target
katrí → *katrí*	*tríka* → *tríka*
toklí → *klí*	*klíto* → *klíto*
piflá → *iflá*	*flápi* → *vlápi*
kixró → *ixkó*	*xróki* → *óti*
povrí → *toví*	*vrípo* → *vípo*

In a comparison of children's performance in word-initial TT and word-medial TT, a significant difference appears.

A visual examination of table 6 table shows that most children performed better at medial TT than at initial TT. The top right sector is much more populated than the bottom left one, and the difference in statistically significant (χ^2=11.3, p=0.001, DF=1). There are a large number of children that performed well at medial TT and poorly at initial TT, while there were few children that performed better at initial TT than at medial TT[17]. Some

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[17] In the cases of children that performed better at initial TT, the difference between the word-initial condition and the word-medial condition is consistently small: either

Table 6. Number of correct responses for #TT and –TT for each child

#TT \ -TT	0	1	2	3	4	5
0	//// //	//// /	//	/		
1	/		///	/	///	/
2	//	/		//	//	/
3			//	//// /	//	//
4				//	////	//// /
5					/	////

examples of individual children's performance are given below. Kostantinos (17a) performed adult-like in the word-medial condition, while his performance in the word-initial condition was very poor. Manouela's performance (17c) was very poor in both conditions, while Mario (17b) gave correct responses about half of the time in both conditions.

(17)   a. Kostantinos (2;11,17)

        -TT: 5 out of 5 target   #TT: 1 out of 5 target
        poftí → *poftí*   *ftípo* → *ftípo*
        kaxtí → *kaxtí*   *xtíka* → *tíxa*
        tovðí → *tovðí*   *vðíto* → *víto*
        kiɣðó → *kiɣðó*   *ɣðóki* → *ðóki*
        pivɣá → *pivɣá*   *vɣápi* → *ɣápi*

    b. Mario (3;03,01)

        -TT: 3 out of 5 target   #TT: 2 out of 5 target
        poftí → *poftí*   *ftípo* → *ftípo*
        kaxtí → *taxtí*   *xtíka* → *xtípa*
        tovðí → *oðí*   *vðíto* → *víto*
        pivɣá → *tivɣá*   *ɣðóki* → *vðóki*
        kiɣðó → *iɣó*   *vɣápi* → *xápi*

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one response difference (1-0, 2-1, 3-2, 4-3, 5-4) or a maximum of two responses difference (2-0) (see table 6).

c. Manouela (2;11,19)

-TT: 1 out of 5 target	#TT: 0 out of 5 target
kaxtí → ixtí	*ftípo → pípo*
poftí → xutí	*xtíka → píka*
tovðí → tuvlí	*vðíto → θíto*
kiɣðó → tliɣó	*ɣðóki → klóki*
pivɣá → fijá	*vɣápi → kápi*

In order to give a complete picture of the data, some further comparisons are briefly presented here. Word-medial sT and word-medial TT were not significantly different (χ^2=1.684, p=0.194, DF=1), and neither were word-medial sT and word-medial TR (χ^2=0.1, p=0.752, DF=1) or word-medial TT and word-medial TR (χ^2=0.676, p=0.411, DF=1). Moreover, children performed significantly better at word-medial sT than at word-initial TT (χ^2=22.5, p<0.001, DF=1), while no such difference was detected in a comparison of word-initial sT versus word-medial TT clusters (χ^2=0.641, p=0.423, DF=1).

To sum up, some children performed better at word-initial sT than TR, while others performed better at TR than at sT, creating a balance in the overall results. Children's performance was systematically worse at word-initial TT than at word-initial sT and word-initial TR. In a comparison with the word-medial position, no difference was found in children's performance at sT (initial versus medial) and TR (initial versus medial), while there was a difference between word-initial and word-medial TT.

4.2 Discussion

4.2.1 Extrasyllabicity-problems

The results regarding initial sT versus initial TR were analogous to findings from the acquisition of other languages. No overall difference was found between initial sT and initial TR clusters. These results were representative of tendencies found in the acquisition literature on other languages, with some of the children acquiring sT before TR and some following the opposite path.

These results, combined with the results for initial TT and initial TR (i.e. significantly better performance at word-initial TR) are particularly problematic for the extrasyllabic analysis of sT and TT (see representations in (1) and (2), section 2.1). Extrasyllabicity would only be able to account for one set of data: either TT versus TR, or sT versus TR. The TT versus TR results could be explained by an extrasyllabicity model according to which extrasyllabic structures are more marked than regular branching onsets. This (hypothetical)

model, in conjunction with our assumption that structure determines acquisition order, would cover poorer performance at TT than at TR, under the reasoning that extrasyllabic TT is more marked than regular branching onset TR and is therefore expected to be acquired later. However, this model would fail to tackle the paradox of sT versus TR variation, as, following this reasoning, extrasyllabic sT should also be acquired later than branching onset TR. Consequently, such a model would not be able to cover the data and would need to be abandoned. Similarly, the TT versus TR data would not be covered by the amended extrasyllabicity proposals discussed in section 2.2 either – namely a) that extrasyllabicity can be acquired before or after branching onsets, and b) that in some children's grammar, extrasyllabic clusters are structured like affricates, and are therefore acquired before branching onsets. Any such proposal would cover the data it was designed to explain (sT-TR variation), but it would have to answer the question of why the same variation is not found in TT versus TR acquisition. Either way, the results are problematic for the extrasyllabic approach. Evidence for the different nature of sT and TT was also found in the comparison with their word-medial counterparts. Although word-initial TT was acquired later than word-medial TT, such imbalance was not found with sT clusters.

In order to account for the data, it would be possible to add an auxiliary hypothesis that assumes two different kinds of extrasyllabicity, one for initial sT and one for initial TT. However, this would not be enough: we would further have to stipulate the order of acquisition of these different structures. Specifically, we would have to stipulate that sT-type extrasyllabicity is acquired before TT-type extrasyllabicity. If TT was found to be acquired before sT, extrasyllabicity could simply stipulate that it is TT that is acquired before sT, and thus be made consistent with the opposite reality.
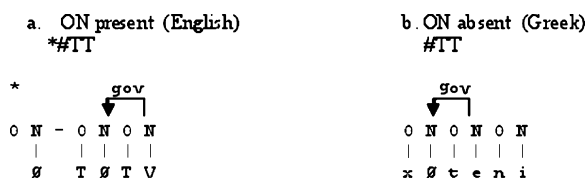
We conclude that an analysis that assigns extrasyllabic structures to initial sT and initial TT cannot account for the data. In the remainder of the paper, I present an alternative approach to word-initial clusters and to clusters in general, and I examine whether this approach can cover the familiar as well as the newly presented data.

4.2.2 Towards an analysis
If we try to categorise word-initial clusters based on the child data presented here, the division appears to be between TR and sT on one hand and TT on the other hand. The acquisition of TT clusters requires an extra step when compared to the rest of the word-initial clusters tested.

This descriptive division corresponds to a theoretical division that has been suggested on entirely different grounds, based on adult language phenomena.

Scheer (2000; 2004), divides (adult) languages into those that allow word-initial TT clusters and those that do not. The theoretical distinction he proposes is the absence versus presence of an onset-nucleus pair at the left margin of the word. The proposal is part of a phonological system known as CVCV, a development of Government Phonology (Charette, 1990; Harris, 1994; Kaye et al., 1985; 1990). CVCV defines structure according to relationships that segments establish along the syntagmatic dimension i.e. governing and licensing relations with what follows and what precedes, thus eliminating vertical-branching structure.

(18)   Syntagmatic representations: *péfto* '(I) fall', *míti* 'nose', *xténi* 'comb'

The examples in (18) show the representations of three Greek words. As may be seen, the skeleton is a sequence of onsets (consonantal positions) and nuclei (vocalic positions), which may or may not enjoy segmental instantiation (Lowenstamm, 1996). An empty nucleus Ø is allowed to exist if it is governed[18], i.e. if it is followed by a nucleus that is not itself governed. Example (18a) shows how the mechanism of Government allows the existence of (word-medial) clusters of non-rising sonority: the empty nucleus between the two cluster members is governed by the following full (non-governed) nucleus.

Based on Lowenstamm's (1999) proposal that the left margin of the word corresponds to an onset nucleus pair without any segmental content (ON), Scheer proposes a parameterisation of the initial ON. The existence of an initial ON pair in a language creates a ban on word-initial TT clusters. This is because the empty nucleus of the initial ON would fail to be governed, since the following nucleus (within the TT cluster) is itself empty and governed (19a). Absence of the initial ON in a language makes the existence of initial TT clusters possible (19b).

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[18] This is known as the Empty Category Principle (Scheer, 2004, for earlier formulations of the principle in Government Phonology see Kaye et al., 1990), which also specifies other conditions that allow a nucleus to be empty, such as the nucleus being inside a licensing domain – see below.

(19)   Parameterisation of initial ON and typology of initial TT clusters

On the other hand, the presence or absence of the initial ON pair is immaterial to the existence of word-initial TR and sT clusters, which involve structures that enable the governing of the empty nucleus of the initial ON. Specifically, TR clusters (initial and medial) are formed by licensing of the cluster[19], which allows the nucleus inside the cluster to be empty while being ungoverned, allowing it thus to govern the empty nucleus of the ON pair (20a) (Scheer, 2004). Moreover, CVCV has inherited from Government Phonology the special status of *s* in word-initial sT clusters, as mentioned in section 2.1 (Kaye, 1992). The direct translation of Kaye's 'magic licensing' in CVCV is that *s* in sT clusters has the ability to govern the empty nucleus of the initial ON pair itself (20b).

(20)   Initial TR and initial sT clusters

The structure proposed in CVCV for word-initial clusters of non-rising sonority finds independent support in diachronic lenition and fortition phenomena (Seigneur-Froli, 2003; 2004; 2006). For instance, in Greek, the first member of obstruent-obstruent clusters in word-initial position behaves like the first member of such clusters in word internal position. An example of this is a diachronic lenition process whereby the first member of clusters of two

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[19] The idea that an (onset) cluster must be licensed by its nucleus was first developed in Government Phonology by Charette (1991). The main difference between the Government Phonology and the CVCV theoretic view of these clusters is that in Government Phonology the obstruent is the head of the cluster, while in CVCV theory it is the sonorant that receives licensing by the nucleus for the establishment of the domain.

voiceless stops in both word-initial and word-medial position underwent frication (e.g. *ptero > ftero* 'wing', *epta > efta* 'seven'). In CVCV, such identical behaviour of the two consonants is expected, since the two consonants are in identical positions: before a governed empty nucleus ((21a-b), relevant positions in bold).

(21)　　Before a governed empty nucleus

These positions have the same structure, as that is defined in CVCV by the governing and licensing relations that target them (in this case neither government nor licensing; for more on segmental effects of government and licensing the reader is referred to Ségéral and Scheer, 2001).

This presents an advantage for CVCV as compared to syllable-based accounts involving word-initial extrasyllabicity (see e.g. Steriade, 1982), which face difficulties in trying to explain such identical behaviour. As Seigneur-Froli (2006) argues, the lenition effect just described cannot be satisfactorily explained in the latter approach: the two consonants in question are different: one is extrasyllabic, while the other is a coda consonant.

CVCV theory provides us with a series of syntagmatic forces covering (adult) language typology. These include: Licensing, regulating the existence of TR clusters (see representation in (20a)), Government, responsible for the existence of (word-medial) TT clusters (see representation in (18a, c), and word-initial ON pair, regulating the presence of word-initial TT clusters (see representations in (19))[20]. These forces, in conjunction with a theory of learnability, can give us a model of consonant cluster acquisition. I briefly sketch this model here, with particular emphasis on word-initial clusters.

I follow here Dresher and Kaye (1990) (see also Dresher, 1999) in assuming that parameters at the initial state have a default (unmarked) setting, which switches to the marked setting if positive evidence is encountered. This is based on the hypothesis that only positive evidence can be used in acquisition (Chomsky, 1986, see also Gibson and Wexler, 1994). For example, TR

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[20] CVCV (Scheer, 2004) and Government Phonology also involve a number of other parameters which regulate the existence of alternating vowels, word-final consonants and word-final consonant clusters.

clusters are only permitted under the positive setting of the Licensing parameter: the forms permitted under the negative setting of the parameter are a proper subset of those allowed under the positive setting[21].

(22) Small oval: forms under -License
   Large oval: forms under +License
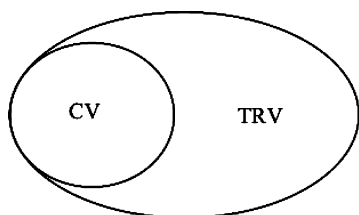
We can therefore determine that the marked setting is the positive one (+License). The existence of the cluster will constitute the cue (trigger) for a change of value. Similarly, +Govern is the marked setting of the parameter responsible for the existence of word-medial TT clusters.

I propose that the unmarked setting for the Initial ON parameter is the Yes value. The existence of this ON pair is responsible for the absence of word-initial TT clusters in early child language. These clusters will appear when the setting of the parameter switches to the No value.

The choice of the unmarked setting is based on the fact that the set of possible forms in grammars with an initial ON is a proper subset of the possible forms in languages without an initial ON.

(23) A subset relation
      Small oval: forms under Initial ON Yes
      Large oval: forms under Initial ON No

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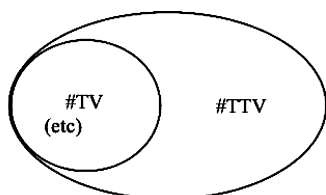
[21] Note that this type of subset relation is normally not found in the parameters controlling metrical systems (Dresher and Kaye, 1990). The task of the linguist studying the parameters of metrical systems is thus considerably harder.

As with other parameters, the unmarked state cannot be the grammar producing the superset of forms, because the move to the subset grammar would require negative evidence. In the absence of negative evidence in acquisition, we have to posit the subset grammar, the one with an initial ON, as the unmarked state.

However, such a decision faces a potential problem, regarding languages that have no clusters at all. Such languages have a negative setting for the Government parameter, which bans word internal TT clusters. At the same time, this parameter setting makes the existence of an initial ON pair impossible, since government of the empty Nucleus of the ON pair would not take place. Such reasoning is followed by Kula and Marten (2009), who conclude that clusterless languages have no initial ON.

We are thus presented with a paradoxical situation, with regard to the values of the initial ON parameter. We have identified three language types of increasing degrees of complexity (in terms of TT clusters) and have assigned a No setting to the least and most complex of them (languages without TT and languages with internal and initial TT), and a Yes setting to the middle one (languages with internal TT clusters only).

(24) A paradox

Setting of the ON Parameter	TT clusters in the language
No	—
Yes	Internal TT only
No	Internal TT and initial TT

This typologically paradoxical situation makes it difficult for the linguist to decide on the unmarked setting of the ON parameter. Moreover, it presents a problem for first language acquisition. We are forced to say that the parameter starts with a No setting, at the initial state, and when the child encounters word internal TT clusters the parameter switches to Yes, and goes back to No when word-initial TT clusters are encountered. This switching back and forth of a binary parameter would make the acquisition process non-deterministic: in deterministic learning models, a change from the unmarked to the marked value is possible, but a change from marked to unmarked is interdicted. The situation in (24) might have the unfortunate consequence of forcing us to subscribe to a non-deterministic model, which allows switching back and forth of a parameter despite advantages of the more constrained nature of deterministic acquisition models (Berwick, 1985; Marcus, 1980).

However, the violation of determinism is only apparent. Having argued that the trigger for a change from Yes to No of the ON parameter is the existence of word-initial TT clusters, we established the Yes value as unmarked.

This value only becomes available when the Government parameter gets fixed at the plus value. When the Government parameter is set to the minus value, the Initial ON parameter must be set to No. This (-Govern, No Initial ON) is the initial configuration of the parameter set. The difference between the marked and unmarked settings can be seen when the Government parameter switches to plus. As soon as this change takes place, the Initial ON parameter goes back to Yes, which is the unmarked setting, and a change to the marked No setting will take place if the appropriate evidence of initial TT clusters is encountered (see Dresher and Kaye, 1990 for a discussion of a similar case regarding metrical structure).

Word-initial TT clusters thus appear when the initial ON pair has disappeared from the child's grammar, and the Government parameter is set to the plus value. In contrast, the only requirement for the existence of word-medial TT clusters is a marked setting of the Government parameter. The conditions for the existence of word internal TT clusters constitute a proper subset of those for the existence of word-initial TT clusters ((25).

(25)   A subset relation
Small oval: conditions for word-medial TT
Large oval: conditions for word-initial TT
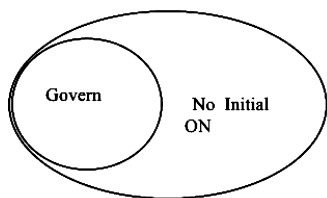
Thus, whenever a (developing) grammar allows TT clusters word-initially, we expect to find TT clusters word internally, too. This is consistent with our experimental findings, which showed better performance at word-medial TT than at word-initial TT. Word-initial TT is acquired later than its word-medial counterpart since initial TT, unlike medial TT, has the extra requirement that the ON pair be absent.

Similarly, word-initial TT clusters only appear when the initial ON pair has disappeared from the child's grammar, while initial sT and initial TR clusters have no such requirement. This can explain the later acquisition of initial TT when compared to other word-initial clusters.
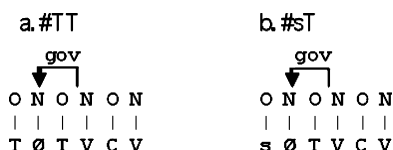
(26)   Acquisition stage n-1: ON present: Initial sT, TR, no TT clusters
        Acquisition stage n: ON absent: Initial sT, TR, TT clusters

This is also consistent with our experimental findings, and more specifically with children's significantly better performance at word-initial sT and word-initial TR than at word-initial TT.

Note that once the initial ON pair has disappeared from the child's grammar (in other words, when initial TT is acquired), initial TT and initial sT have the same structure, as that is defined by the governing and licensing relations that target them (see structures in (27a) and (27b) respectively).

(27)   Word-initial TT and sT

```
    a. #TT                    b. #sT
        gov                       gov
       ┌──┐                      ┌──┐
       ▼  │                      ▼  │
   O  N  O  N  O  N          O  N  O  N  O  N
   |  |  |  |  |  |          |  |  |  |  |  |
   T  Ø  T  V  C  V          s  Ø  T  V  C  V
```

Thus, evidence than in adult language sT and TT behave identically, such as the Attic Greek reduplication data presented in (4), can also be covered by CVCV.

How does the CVCV model account for the behaviour of initial sT versus initial TR clusters? Recall that initial sT can be acquired before or after TR. In the CVCV model each cluster type requires one marked setting, of two parameters that are independent from each other. sT requires the marked setting of the Government parameter, while TR requires the marked setting of the Licensing parameter. The requirements for the two clusters form independent sets that do not create an intersection.

(28)   Two independent sets
Left oval: requirements for #sT
Right oval: requirements for #TR

```
   ⬭ Govern        ⬭ License
```
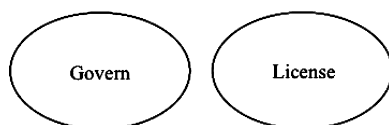
Government and Licensing are independent parameters[22] (one is not a prerequisite for the other), and as such, either of the two can move to the marked setting first. Consequently, some of the children will acquire sT first, others

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[22] Cf. Cyran (2003).

TR, and in some cases the two cluster types may appear simultaneously. This analysis can thus account for the puzzle of sT versus TR acquisition.

The difference in performance between word-initial and word-medial TT contrasts with the lack of significant difference in performance between the remaining word-initial cluster types and their respective word-medial counterparts. In the CVCV model outlined above, this is explained by the assumption that initial and medial TR and initial and medial sT are regulated by the same parameters: Licensing for the former cluster pair and Government for the latter pair. A switch of the Licensing parameter to the marked setting will mark the appearance of both initial and medial TR, while a switch of the Government parameter to the marked setting will trigger the appearance of both initial and medial sT clusters.

Moreover, recall that the Government parameter regulates the existence of all word-medial clusters of non-rising sonority. Consequently, once the parameter setting moves to the marked value, word-medial TT clusters will also appear. This is consistent with our experimental findings. There was no difference in performance between any of the word-medial cluster pairs tested: medial sT clusters versus medial TT clusters, medial TT clusters versus medial TR clusters or medial sT clusters versus medial TR clusters as mentioned above. Moreover, word-initial sT and word-medial TT are both controlled by the Government parameter, and no difference in performance between the two was found in our experiment.

To sum up, CVCV theory (Scheer, 2004) coupled with an appropriate learning theory (Dresher and Kaye, 1990) can provide a better fit for our experimental data than models that assume word-initial extrasyllabicity.

Note that the use of the branching-free structure of CVCV in acquisition frees us from a redundancy present in other systems that involve vertical representations. For example, in Government Phonology (Charette, 1990; Harris, 1994; Kaye et al., 1985; 1990), two separate mechanisms are responsible for the same function: a syntagmatic mechanism (government-licensing) and an arboreal mechanism (branching rhymes) both determine the structure of clusters of non-rising sonority. This is reflected in the fact that either of the two mechanisms can be assumed to be parametric: government licensing (Charette, 1990; 1991) or the branching rhyme structure (Pan, 2005, see also Fikkert, 1994). Eliminating the branching structure, as in CVCV, eliminates this redundancy (see also Scheer 2004, Takahashi 1993; 2004).

Finally, the CVCV model covers the existence of adult languages that allow any of the cluster combinations allowed in child language. For example, languages that allow TR and sT clusters initially and medially, but TT clusters

only medially, such as English, and languages that allow all three cluster types in both positions, such as Greek.

However, it is argued that there exists a typological universal concerning complex onsets and codas[23], which is inconsistent with the assumption followed here that government (which controls medial codas, including TT clusters) and licensing (which controls complex onsets, i.e. TR clusters) are independent. Precisely, it is argued that the presence of a complex onset in a language implies the presence of a coda in that language. There are languages that allow both structures (e.g. English and Greek), and languages that allow codas but no complex onsets (e.g. Hungarian), while there are no languages that allow complex onsets but no codas (Kaye and Lowenstamm, 1981).

Various models in different frameworks have been proposed in order to capture this universal (see e.g. Baertsch and Davis, 2003, Cyran, 2003, Kaye and Lowenstamm, 1981). For example, Kaye and Lowenstamm (1981) formalise the typological observation as a constraint on structure: if a language allows a marked onset (i.e. branching onset), then it allows a marked rhyme (i.e. branching rhyme). Moreover, Cyran (2003) stipulates an implicational relationship regarding government and licensing: if, in a language, nuclei can license (formation of TR clusters), then they also have the ability to govern (formation of coda-onset clusters). Note that these assumptions do not follow from any theoretical necessity, they are stipulations made solely in order to capture the typological observations.

Part of the motivation behind these models is the developmental pattern reported in previous acquisition studies with regard to the order of acquisition of codas and complex onsets (Levelt and van de Vijver, 2004; Levelt et al., 2000). For example, Baertsch and Davis (2003) set out to account for the implicational universal in adult language typology as well as for the developmental pattern whereby the acquisition of codas precedes that of complex onsets. With regard to the latter, they quote Levelt et al. (2000), who report that CV syllables appear first in acquisition, followed by CVC and finally CCV syllables. However, in our data there was no evidence that word-medial codas are acquired before word-medial complex onsets.

Two questions arise here. Firstly, do our findings contradict those of other acquisition studies that found that the acquisition of codas precedes that of complex onsets? And secondly, how can we reconcile our findings with the existence of an implicational universal regarding codas and complex onsets in adult language typology?

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[23] I use the word 'coda' here following the widely used terminology, although CVCV does not involve such constituents.

The response to the first question is no. The question is a matter of termi-nological confusion surrounding the term 'coda'. Studies that found earlier acquisition of codas (Levelt and van de Vijver, 2004; Levelt et al., 2000) use the term 'coda' without making a distinction between word-medial codas and word-final single consonants. In the corpus analysed by these researchers (namely, the Fikkert-Levelt corpus of child language (Fikkert, 1994; Levelt, 1994; MacWhinney, 2000) word-final single consonants are acquired before branching onsets. However, the data show no such implication with respect to medial codas and complex onsets. The examples in (29) show that Jarmo could produce complex onsets at a time when he could not produce word-medial codas (Fikkert, 1994).

(29)   a. Complex onsets
       kla:r → kla: 'ready'   1;11,06

       b. Medial codas
       'rarkəns → 'kakəs
               → 'fakəs   'pigs'   2;0

Therefore, these studies do not make any claims about the acquisition of com-plex onsets as compared to medial codas, which is the issue in question here.

With respect to the existence of an implicational universal in adult language typology, the situation is not as clear. It is generally accepted that there exists an implicational universal regarding complex onsets and codas. However, there are a number of languages that are accepted as potential counterexam-ples to the universal, even by its supporters (Davis and Baertsch, 2006). For example, Davis and Baertsch (2006) report that some Yanomami dialects in Brazil have a $(C_1)(C_2)V$ syllable structure, with TR as the only cluster type allowed (Migliazza, 1972). The examples in (30) show TR clusters in word-initial and word-medial position (from Milliken et al., 2002).

(30)   *prika* 'pepper'
       prohe 'loose'
       tukri 'piranha'

The following example (Dixon and Aikhenvald, 1999) shows a complex verb and illustrates the otherwise CV structure of Yanomama with the exception of a single TR (here *pr*) cluster.

(31)   ʃ*ama*   *e-kɨ-pata-rə-hore-pɨ-pra-ma-re-hərɨ*-no-ve-ɨ
       tapir   OBL-DL-AUGMENTATIVE-TOPIC-rush.off-DL-DISCONTINUOUS-
                CAUS-TELIC-DIRECTIONAL-ACCOMPLISHED-AFFIRMATIVE-
                EYEWITNESS
       'making two huge tapirs rush away'

Notably, Yanomama is not the only language that has been reported as having complex onsets while lacking codas. Besides Yanomama, Davis and Baertsch (2006) also mention Piro, Mazateco and Vata. In the same vein, Blevins (1995) also reports Pirahã and Arabela. However, the status of these languages as counterexamples has been the subject of much debate (see Kaye, 1985 on Vata, Lin, 1997 on Piro, Steriade, 1994 on Mazateco). Although I do not intend to settle the debate here, for the purposes of our investigation suffice it to say that the existence of the implicational universal under discussion is yet to be confirmed. Therefore, it may turn out that the various theoretical stipulations that have been made in relation to this issue are unnecessary.

Finally, in adult language, there seems to be an implicational universal regarding word-initial and word-medial sT clusters: to my knowledge there are no languages with initial sT but no medial sT, while there are languages with medial sT and no initial sT (e.g. Spanish). The existence of languages like Spanish is not consistent with the CVCV model outlined here: if initial and medial sT are controlled by the same parameter, then a language that allows one of them should also allow the other. The acquisition data, which provided no evidence for earlier acquisition of medial sT, is also inconsistent with the observed adult language typology. A model that is based on the adult language typology of sT clusters (see Pan, 2005) would predict earlier acquisition of medial sT clusters, a prediction that is not supported by our experimental results. I have nothing insightful to say on this issue and I leave it for future research.

5 Conclusion

First language acquisition provides a valuable testing ground for different syllabic theories. The contribution of this study to the evaluation of competing phonological theories consists in that it showed how CVCV theory (Scheer, 2004) can account for developmental data that is problematic for more traditional models.

Of particular importance for phonological theory are the findings regarding word-initial TT and sT clusters, especially because the acquisition of the former had previously received little attention. It was shown that, contrary to claims that the two cluster types have the same structure, they behaved differently in acquisition. The order of acquisition can be accounted for by a CVCV acquisition model, which assumes that the necessary and sufficient conditions for initial sT clusters form a proper subset of those for initial TT clusters. The model was briefly developed here, by combining independently motivated mechanisms of CVCV theory (such as the word-initial ON pair),

in conjunction with the model of learnability presented in Dresher and Kaye (1990). More languages that allow initial TT clusters need to be investigated in order to test the validity of the findings and generalisations. Testing more languages is also necessary if we are to discover more about the acquisition of consonant sequences and positions that do not occur in Greek, such as word-final clusters. A number of other issues pertaining to first language acquisition have been left untouched here, such as error patterns (in particular cluster reduction patterns), acoustic properties of the clusters produced and, finally, an examination of cluster perception in conjunction with production. These are left for future research.

Furthermore, an important aspect of CVCV theory, mentioned here only briefly, is its contribution to the study of sub-segmental phenomena, such as lenition and fortition effects. A first attempt to test CVCV principles regarding sub-segmental phenomena in the field of first language acquisition is made in Sanoudaki (2009). However, further research is required in this field. This will also enable us to examine the internal composition of *s* and shed some more light on the magic of *s*-clusters.

Acknowledgements

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