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Consonant clusters in child phonology and the directionality of syllable structure assignment*

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ABSTRACT

The production of target consonant clusters at early stages of acquisition is analysed from a phonological representational perspective. The data stem from five normal monolingual German and four normal monolingual Spanish children at ages from 0;9 to 2;1, observed in naturalistic settings. At the beginning stages, target clusters are reduced to a single consonantal position, due to lack of branching of the syllabic constituents. This finding coincides with other results in the literature, which have in general been explained by means of universal principles. Nevertheless, there is an essential difference between the German and the Spanish data: German children tend to prefer the first consonant and Spanish children the second one. This difference can only be explained in terms of parameterization of syllabification, which in German takes place from left to right and in Spanish from right to left. At later stages, when clusters begin to be produced with two consonantal positions, they offer evidence for the beginning of branching of syllabic constituents, due to parameterization, and for the chronological order of the setting of the subsyllabic parameters. Our data offer evidence in favour of the following acquisitional hierarchy: CV > CVC > CVCC > CCVCC.

INTRODUCTION

Target consonant clusters of both normal and language-impaired children have been the subject of investigation in first language phonological ac-

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quisition research. Previous work focused on child production of consonant clusters (Smith, 1973; Greenlee, 1974; Stoel-Gammon & Dunn, 1986), whereas most recent work has reconducted research from production to representation (Spencer, 1986; Iverson & Wheeler, 1987; Chin & Dinnsen, 1992). The investigation presented in this paper aligns with the latter, in concentrating on the REPRESENTATION of consonant clusters. It is based on data from normal monolingual Spanish and normal monolingual German children from 0;9 to 2;1.

At the early word stage, syllabic constituents do not branch, so only one segment can be planned at the onset, at the nucleus and, later on, at the coda. As soon as the rhyme parameter is activated and the rhyme branches (Kaye, 1989), the maximal syllable schema consists of a vowel, surrounded by one consonant at each side: (C)V(C) (Branigan, 1976; Menn, 1978; Locke, 1983; Lleó, 1986; Carreira, 1991; Vihman, 1992). According to the universal hierarchy of acquisition (Carreira, 1991; Fikkert, 1994), the activation of the onset parameter takes place after the activation of the rhyme parameter, giving way to CCVC. If the target language has branching codas like German, the switching of the coda parameter produces CCVCC syllables.

The preferred minimal syllable structure is the CORE SYLLABLE, CV, until further positions are acquired in later development. The development of syllabic structure can be represented as in Fig. 1. The canonical syllable

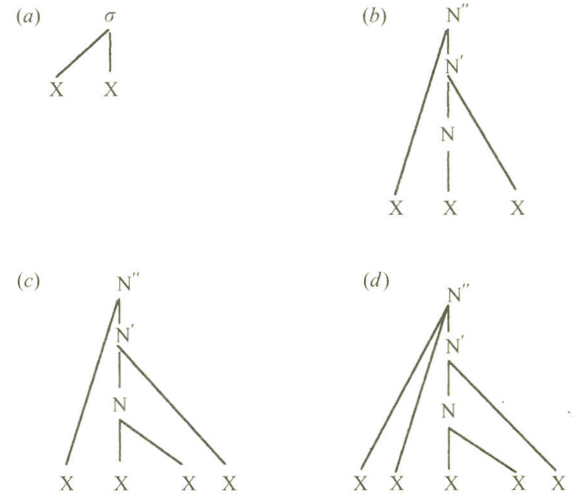

Fig. 1. The evolution of syllabic structure.

scheme is independent of segmental properties and it exclusively represents structural aspects. That is, the X slots represent the structural units of the syllable, where X is associated with a consonant, with a glide or with a vowel, depending on the constituent it belongs to (Clements & Keyser, 1983; Kaye, 1989; Goldsmith, 1990).

During the period reported in this paper, when the preferred syllable scheme consists mainly of simple non-branching constituents, only one single prevocalic segment can be produced (Fig. 1*a*) and later on a single postvocalic segment, as well (Fig. 1*b*). Target clusters are thus produced by means of one single consonantal position. The assumption has often been made that the selection of this segment is not arbitrary but dependent upon universal conditions of feature markedness or sonority (see Spencer, 1986; Bernhardt, 1992; Chin & Dinnsen, 1992). Even though these hypotheses are partly right, our data argue in favour of an additional conditioning factor: the directional assignment of syllable structure, which is determined by the phonological characteristics of the corresponding target language, and the corresponding directional representation of clusters.

Once syllabic constituents begin to branch, target consonant clusters are produced with two consonantal positions by the child. The analysis of clusters articulated as such allows us to establish the beginning of syllabic constituent branchings, i.e. the setting of the corresponding parameters.

METHOD

Subjects

The data derive from a longitudinal investigation of five children acquiring German in Hamburg and of four children acquiring Spanish in Madrid. Data collection began when the infants were nine months old. All the children except one were first-born in middle-class, monolingual families and had no siblings at the beginning of the project; one Spanish child, José, had an older sister. The German infants were two girls and three boys; the Spanish infants were one girl and three boys.

Procedure

The German children were audio-recorded twice a month using a high-fidelity Sony TCD-D10 PRO cassette recorder and a portable Beyerdynamic microphone concealed in a vest which they wore. The Spanish children were both video- and audio-recorded once a month with a Panasonic video camera and the same audio equipment used for the German children. The children were all recorded at their homes in unstructured play sessions in interaction with both the mother and one investigator. Only toys belonging to the child being recorded were used in most sessions; occasionally object naming tasks were encouraged with the help of picture books, especially in the Spanish recordings. In the German sessions, the situational context was noted by a second investigator. All sessions, the German as well as the Spanish ones, were transcribed by the German research team in Hamburg. Transcriptions were made by at least two trained phoneticians using IPA notation. All sessions from 0;9 to 2;1 were considered for analysis. In those cases for which no data were available at 2;0, namely Britta and Juan, the 2;1 session was included in the analysis. The data were analysed with CLUSTERS, a database developed within *4thDIMENSION®*. This database consists of 489 Spanish and 771 German target clusters.

Method of analysis

The occurrences of clusters within words were considered separately according to their position: initial, final and medial. The differentiated analysis of clusters, depending upon their position, is required by their non-uniform suprasegmental organization. Initial and final clusters belong to one syllable, i.e. they are tautosyllabic, whereas medial clusters are heterosyllabic.

Initial clusters are primarily defined as syllable initial or onset clusters, a subset of which are also word initial. In a similar fashion, final clusters should be understood as syllable final clusters, most of which are also word final. They are loosely referred to as coda clusters, although some of them may belong to both the nucleus and the coda properly (see *Correct cluster production and parameterization*, below). Initial and final clusters are thus represented as in (1),

(1*a*) Onset: $_{\sigma}[\mathrm{CCV}\ldots$
(*b*) Coda: $\ldots\mathrm{VCC}]_{\sigma}$

the two C positions having to be prosodically licensed, i.e. associated with the next higher constituent ONSET or CODA. Following Goldsmith (1990: 107f.), there are restrictions on licensing phonological features: the syllable is to be considered as a primary licenser authorizing the occurrence of various phonological features, and the coda is a secondary licenser that allows for more restricted types of segments.

Conversely, medial clusters refer to word medial position, with the adjacent consonants belonging to two different syllables, hence to two different constituents, as in (2*a*). A structure such as (2*b*), where the consonants belong to a single syllable, has been subsumed under the onset or (syllable) initial clusters.

(2*a*) $\ldots\mathrm{VC}]_{\sigma\sigma}[\mathrm{CV}\ldots$
(*b*) $\ldots\mathrm{V}]_{\sigma\sigma}[\mathrm{CCV}\ldots$

Clusters are associated with two skeletal positions, i.e. one skeletal position has to be available for each member of the cluster. According to current

TABLE 1. *Target consonant clusters in German and Spanish*

a. Initial clusters		
	German:	fl, pl, bl, kl, gl, bR, dR, gR, tR, fR, mj, kw
	Spanish:	fl, bl, pl, kl, gl, bɾ, dɾ, tɾ, kɾ, gɾ, fɾ, gw, mj, dj, tj, pj, nj, ʎw, pw
b. Final clusters		
	German:	nʃ, nt, mt, ŋk, çt, st, kt, ft, pt, lt, lʃ, lf, ln
c. Medial clusters		
	German:	st, sç, nt, kt, kn, km, nl, ʃb, ʃl, ʃn, ft, ŋk, lk, mb, mf, ml, lm, ŋm, Rt, ps, pm, fg
	Spanish:	mp, mb, nl, nx, kt, βl, ɾk, ɾm, ɾɣ, ɾβ, ɾs, ɾð, lk, lβ, ld, ls, lθ, sk, sp, st, ɣw, mj, nj, pj, bj, tj, dj

phonological theory (Sagey, 1986; Lombardi, 1990; Prinz & Wiese, 1991; Rubach, 1994), affricates, consisting of plosive plus fricative, e.g. [ts] or [pf], are associated with only one position of the skeleton. Because affricates differ from normal clusters in not requiring branching, they are excluded from this analysis. Moreover, the clusters consisting of fricative plus stop (e.g. [ʃt] or [ʃp] in German) are also excluded at word initial and word final position, because, according to current phonological treatments, they either contain an extrasyllabic first segment (Wiese, 1988) or they are to be associated with a single skeletal position (Wiese, 1991). We thus assume that their representation has a special status and exclude them from the general treatment. They will only be dealt with in medial position, where they have to be clearly represented by two skeletal positions, as in (2*a*), one belonging to the coda and the other to the onset of the following syllable.

To test statistical significance, variance measures (two-tailed, Student *t*-tests) were conducted. Probability values were arrived at on the basis of various measurements, calculated separately for German and Spanish, as well as by cross-language comparisons. The value $P < 0.05$ is considered significant and $p < 0.01$ highly significant.

Target consonant clusters

Target-language clusters requiring two skeletal positions constitute the focus of analysis. All German and Spanish clusters relevant for the analysis are given in Table 1. Clusters not appearing as input to the children have been omitted.

In the input data of both target languages, initial clusters consist of an obstruent (a stop or the fricative [f]) and a liquid ([l] or [R] in German, [l] or [ɾ] in Spanish); coronals cannot combine with [l] in either language. Final clusters occur only in German and consist of a sonorant (a nasal or a liquid [l]) plus an obstruent or two obstruents, i.e. a fricative and a stop, or two stops; liquid [l] can also be followed by a nasal. In medial position, both languages allow the appearance of two obstruents, a stop preceded by a fricative in Spanish, and by a fricative or a stop in German.

The string of segments constituted by a consonant and the first member of a raising diphthong, a glide [j] or [w], have also been considered under the onset clusters for the following reasons. In the target grammar, both segments, the consonant and the glide, are associated with a skeletal position each, and bipositionality in the skeleton has been argued to be the main requirement for consideration here. Although in the adult grammar each member of the string belongs to a different constituent – the consonant to the onset and the glide to the nucleus – the child's grammar, having one single skeletal onset slot at its disposal, does not necessarily treat them differently from other clusters. It has been often reported that liquids and glides are fluid categories at the early stages of acquisition: in some languages, for instance German, [l] is often replaced by the glide [j]; in other languages, for instance English, [ɹ] is often replaced by [w].

RESULTS

Reduced clusters

In the child's productions of target consonant clusters, the two consonantal positions of the target are normally reduced to a single one. The segment produced in this single position may coincide with the first position (C1) of the target cluster, with the second one (C2), or with neither, i.e. it might be replaced by a different segment or even deleted. Table 2 shows the numbers and percentages of reductions to C1 and to C2 for each individual child and for both language groups. The percentages refer solely to the comparison between C1 and C2. Some examples are listed in Table 3.

The segmental material with which the child fills the consonantal position is not necessarily identical to one of the target segments, as it is seldom the case that a segment produced by the child is identical to the target. Instead, the segment produced by the child may constitute a natural class with one of the target segments in a narrow sense, i.e. according to place AND manner of articulation, as for instance in Johannes' pronunciation [po̞ːt] for *Brot* (see Table 3*a*). These data are to be distinguished from those in which the produced segment does not constitute a natural class with any of the target segments, as in the pronunciations of *Frau*, *Flugzeug*, *Klein* or *globo* (see Table 3*c*). In these cases, the child does not make use of target features to fill the onsets. In accordance with the onset principle, the empty onsets have then to be filled by context-free assignment of a laryngeal, as in the German words *Frau*, *Flugzeug* and *klein*, or by feature-spreading from a neighbouring onset, as in the Spanish word *globo*.

TABLE 2. *Child production of clusters, reduced to either C1 or C2*

	Onset				Medial				Coda				Total			
	C1	%	C2	%	C1	%	C2	%	C1	%	C2	%	C1	%	C2	%
German																
Bernd	18	100	0	0	0	0	6	100	10	100	0	0	28	82	6	18
Marion	18	95	1	5	3	50	3	50	10	91	1	9	31	86	5	14
Britta	15	100	0	0	0	0	7	100	9	90	1	10	24	75	8	25
Thomas	17	74	6	26	12	35	22	65	11	100	0	0	40	59	28	41
Johannes	46	92	4	8	20	87	3	13	27	90	3	10	93	90	10	10
Total	114	91	11	9	35	46	41	54	67	93	5	7	216	79	57	21
Spanish																
Miguel	15	75	5	25	8	14	51	86					23	29	56	71
María	7	16	38	84	16	29	40	71					23	23	78	77
Juan	11	46	13	54	5	4	117	96					16	11	130	89
José	20	80	5	20	7	11	54	89					27	31	59	69
Total	53	46	61	54	36	12	262	88					89	22	323	78

TABLE 3. *Examples of consonant clusters, reduced to either C1 or C2*

a. C1C2 → C1			
Britta			
1;6	*draußen*	[dausən]	'outside'
1;7	*brauchst*	[baux]	'need' (2.p.s.)
1;7	*Fenster*	[hɛnsʁ]	'window'
1;8	*Brille*	[bel:ə]	'glasses'
1;10	*kleine*	[kajnə]	'small'
Thomas			
1;7	*Grekos*	[giko]	'proper name'
1;9	*Britta*	[bɛtə]	'proper name'
1;10	*dran*	[dan]	'(your) turn'
1;11	*Blüte*	[bitə]	'blossom'
Johannes			
1;10	*Brot*	[po:t]	'bread'
b. C1C2 → C2			
Miguel			
1;7	*guapo*	[vapo]	'pretty'
1;10	*flores*	[lojs]	'flowers'
1;10	*globos*	[loβoç]	'balloons'
1;10	*globos*	[loβo]	'balloons'
Juan			
1;11	*flores*	[lɔle:]	'flowers'
c. Reduction by means of neither C1 nor C2			
Bernd			
1;11	*Frau*	[daw]	'woman'
Marion			
1;8	*Flugzeug*	[ʔuhɪ]	'airplane'
1;10	*Clown*	[dawn]	'clown'
Britta			
1;5	*klein*	[hajn]	'small'
Juan			
1;9	*globo*	[wɔwə]	'Balloon'

Because of the different solutions provided by the particular child to target clusters, several criteria for equivalence to C1 and to C2 were defined. In onset position, in order to be considered as corresponding to C1, the segment had to be an obstruent and have the same point of articulation, in a loose sense, as the target; no identity of sonority was required, because sonority does not seem to be distinctive at this stage. And to be considered as corresponding to C2, manner of articulation was the basic requirement, i.e. the segment had to be a liquid. For coda clusters, point and manner of articulation had to correspond to the target C1 or C2.

An examination of Table 2 reveals a tendency for the German children to articulate the first segment and for the Spanish children the second one. This holds for all three cluster positions.

In onset position the German children prefer C1 and two of the Spanish children, María and Juan, prefer C2. The preference for C1 over C2 in German gives significant results ($p < 0{\cdot}02$) but not a preference for C2 over C1 in Spanish ($p < 0{\cdot}7$). Medially, C2 is the position produced most often in both language groups. The values of the Spanish group exhibit a significant preference in favour of C2 ($p < 0{\cdot}03$), whereas in the German group there is no significant preference in favour of C1 or of C2 ($p < 0{\cdot}8$). In final position, where no interlanguage comparison is possible because of lack of coda clusters in Spanish, the German children produce more C1 than C2, resulting in high significance: $p < 0{\cdot}01$.

Considering the clusters as a whole, independently of their position within the word, the greater numbers of C1 in German result in significance ($p < 0{\cdot}03$) and so do the higher values for C2 in Spanish ($p < 0{\cdot}03$). The comparison across the two languages results in high significance for C1 : $p < 0{\cdot}01$, and in a significant value for C2: $p < 0{\cdot}04$.

The data in Table 2 are complemented with developmental data for each language group, by means of graphics (Figs 2–4), showing the development initially, medially, and totally. Coda clusters, appearing only in German, are not shown separately, but have been included in Fig. 4. The collective

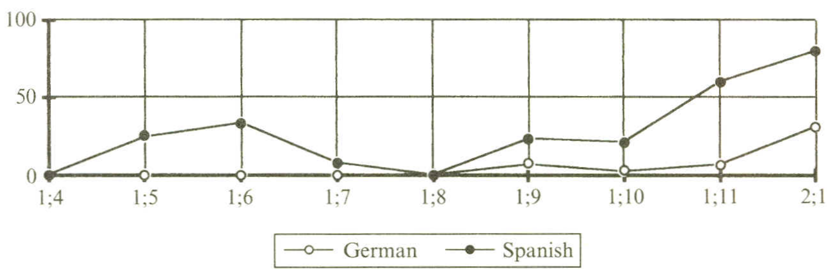

Fig. 2. Reduction of onset clusters to C2 by Spanish and German children along the time axis.

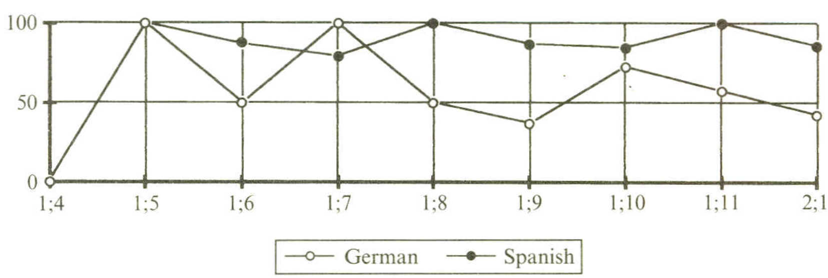

Fig. 3. Reduction of medial clusters to C2 by Spanish and German children along the time axis.

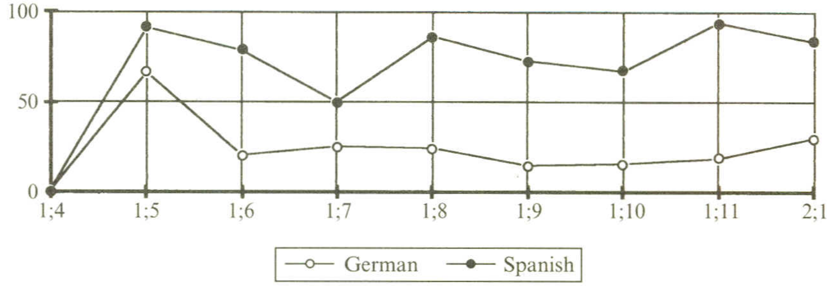

Fig. 4. Reduction of clusters (in all three positions) to C2 by Spanish and German children along the time axis.

TABLE 4. *Reduced clusters according to sonority*

	C1	C2	C1	C2	C1	C2
a. Onset clusters						
	Stop/	sonorant	fricative/	sonorant	fricative/	fricative
German						
Total	81	11	9		24	
%	88·04	11·96	100·00		100·00	
Spanish						
Total	49	58	7			
%	45·79	54·21	100·00			
b. Final clusters						
	fricative/	stop	sonorant/	obstruent		
German						
Total	24	1	43	4		
%	96·00	4·00	91·49	8·51		
c. Medial clusters						
	obstruent/	sonorant	sonorant/	obstruent	fricative/	stop
German						
Total	12	4	11	33	11	5
%	75·00	25·00	25·00	75·00	68·75	31·25
Spanish						
Total	21	84	8	78	7	100
%	20·00	80·00	9·30	90·70	6·54	93·46

development for each language group is quite regular. At the onset, the values for C2 are always lower in German than in Spanish. The Spanish curve for C2 exhibits a rising tendency, whereas that for German displays very low values.

In order to compare the developmental data crosslinguistically in a more accurate way, three points, namely 1;7–1;8, 1;9–1;10 and 1;11–2;1, have been selected and the C2 values appearing in each language at each particular point have been evaluated statistically. At the first point, the preference for C2 shown by the Spanish children is not significant, neither at the onset ($p < 0.5$) nor medially ($p < 0.8$). From 1;9 to 1;10, there is significance only initially ($p < 0.04$), but not medially ($p < 0.4$). From 1;11 to 2;1, the values for C2, higher in the Spanish than in the German data, are significant at the onset ($p < 0.07$) as well as medially ($p < 0.02$).

The graph concerning all clusters, independently of their position, exhibits an almost parallel and stable development (Fig. 4). From 1;5 on, the Spanish C2 curve lies much higher than the German one, being higher than 50% at all points. The German curve lies much lower than 50%, except at 1;5, corresponding only to a single token.

To summarize, the German children show a preference for the first segment of the target cluster and the Spanish children for the second segment.

The values presented above depend upon syllable position, i.e. they have been obtained on the basis of initial, medial and final position. At each position, clusters can be subdivided into subsets, classified according to the sonority values of their consonants (see Table 4). This yields a further procedure to compute the data, which makes possible the comparison with other current investigations in which sonority plays a crucial role (Spencer, 1986; Iverson & Wheeler, 1987; Chin & Dinnsen, 1992). In Table 4, percentages for each cluster have been calculated only in relation to pronunciations reduced to C1 or C2 (as in Table 2).

The onset target clusters have been divided into three subsets, whose members differ in sonority, by assuming that stops are less sonorous than fricatives (Table 4*a*). The first group consists of a stop followed by a sonorant. Stop selection amounts to 88% in German and to 45.8% in Spanish. In the second group, consisting of a fricative followed by a sonorant, the fricative is always produced in German, as well as in Spanish. The third group, consisting of two fricatives, appears only in German. The first fricative is chosen without exception. In final position (in German only), there are two subgroups: a fricative followed by a stop, and a sonorant followed by an obstruent (Table 4*b*). In the child's production of the first group, fricatives make up 96%, and stops 4%. In the second group also the more sonorous segment prevails, with 91.5% sonorants as opposed to 8.5% obstruents.

In medial position, three subgroups have to be distinguished: obstruent plus sonorant, sonorant plus obstruent, and fricative plus stop (Table 4*c*). In the clusters of obstruent plus sonorant, the German children prefer the obstruents (75%) and the Spanish children the sonorants (80%). In the second subgroup, of sonorant plus obstruent, German and Spanish children show a clear preference for the obstruents, which is still higher for the

TABLE 5. *Correct cluster production*

	Onset		Coda		Medial	
	Total	%	Total	%	Total	%
German						
1;5–1;7	0	0·00	13	20·00	8	25·00
1;8–1;10	9	7·63	38	32·20	42	47·19
1;11–2;1	93	17·00	62	11·33	72	37·70
Spanish						
1;5–1;7	0	0·00			4	4·49
1;8–1;10	2	5·06			11	7·59
1;11–2;1	3	3·13			9	6·67

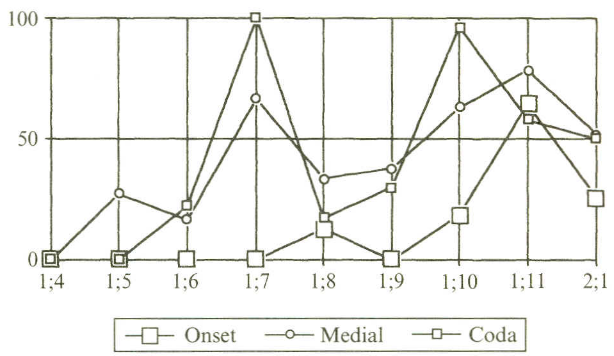

Fig. 5. Development of correct cluster production by the German group. □, Onset; ○, medial; □, coda.

Spanish (90·7 %) than for the German (75 %). In the fricative plus stop clusters, fricatives are preferred in German (68·7 %) and stops are preferred in Spanish (93·5 %).

Correct clusters

Table 5 shows the total numbers and percentages of correctly articulated clusters, initially, medially and finally, for the two language groups, from 1;5 to 2;1. The data have been partitioned into three-monthly periods, beginning at 1;5; before that point the amount of data is almost negligible. The percentages have been calculated out of all target clusters attempted in the corresponding sessions. Figs. 5 and 6 show the proportions of correct clusters along the time axis.

In the German language group, correct production of medial clusters begins at 1;5, of final clusters at 1;6 and of initial clusters at 1;8 or, more probably, 1;10, (at 1;8 there is only a single token and none appears at 1;9).

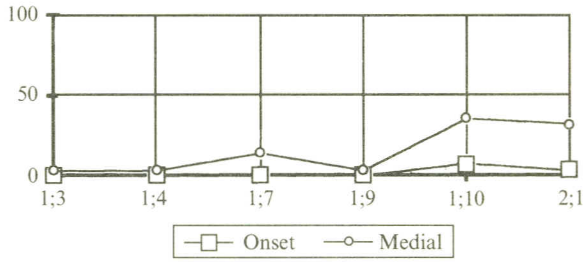

Fig. 6. Development of correct cluster production by the Spanish group. □, Onset; ○, medial.

The three curves exhibit an almost parallel course, the values diminishing at about 1;8, except for onset clusters, and ascending again, medially and finally at 1;9, and initially at 1;10. During the whole period there are more correct clusters medially and finally than initially.

In the case of the Spanish children, too, there are more correct clusters medially than initially. This is also manifested developmentally: the medial curve is always higher than the onset curve. In the German group the value for correct final clusters makes up 34% of all correctly produced clusters. This value is higher than the initial onset one (30%) and lower than the medial one (36%). The final values have a higher rate than the medial and onset values at ages 1;7 and 1;10. Nevertheless, the slightly higher value of correct final over initial clusters is not significant ($p < 0{\cdot}2$). And the difference between correct clusters in medial and in final position is not significant, either ($p < 0{\cdot}3$). In both language groups, correct cluster production is significantly higher in medial than in initial position ($p < 0{\cdot}03$ for German and $p < 0{\cdot}05$ for Spanish).

DISCUSSION

Target cluster reduction and directionality

Non-target-like cluster realization usually consists of producing one position, while the other position disappears without compensation. In phonological acquisition research, there have been various attempts to account for which segment is chosen in the reduction. The acquisitional sequence and current inventory of particular children have been adduced to account for the choice. In this approach, only already acquired segments are possible candidates for the reduced cluster; thus the German target [dʀ] or the Spanish [dɾ] must be realised as [d], if the r-segments have not yet been acquired by a particular child, i.e. are not yet articulated in non-branching constituents. But Iverson & Wheeler (1987) and Spencer (1986) argue that, in general, the segments belonging to the clusters of the target language are already present in the child's underlying entries for the words. And it can often be shown that both segments of a cluster already belong to the child's inventory. In these cases, there is no acquisitional explanation as to why German children prefer the first segment and Spanish children the second segment of the target clusters.

Another attempt at accounting for cluster reduction relates to sonority. Kiparsky (1979) has stated in the SONORITY HIERARCHY HYPOTHESIS (SHH) that the least sonorous segment is the preferred one. Chin & Dinnsen (1992) assume that so-called unmarked segments are preferred. According to both proposals, stops should be preferred over fricatives and obstruents over sonorants because of their less sonorous, hence unmarked status. Spencer (1986: 13) also argues that the reduction of onset clusters leads to non-sonorant, non-continuous segments. Because markedness should be defined in a universal manner, it should dominate the early word phase of ALL children. However, as shown by the results of Table 4, reduction does not take place according to the SHH in all clusters of segments differing in sonority. Thus, some Spanish children prefer the sonorant over the stop in initial (Table 4*a*) as well as in medial (Table 4*c*) onsets; German children prefer the fricative over the stop, and the sonorant over the obstruent in final clusters (Table 4*b*); and they prefer the fricative over the stop in medial clusters (Table 4*c*). Bernhardt (1992: 288f.) has found out that in the production of the clusters /sm/ and /sn/ in English, the more sonorous of the two syllabifiable cluster elements is realized. She accounts for these cases in terms of producing 'the better established segment', because nasals constitute a better established sound class than fricatives. However, this segmental factor cannot account for the different solutions given to clusters in our German and Spanish data.

Although we do not want to deny the influence of the SHH on the child's cluster representations, the data cannot be accounted for by the SHH alone. The selection of one position is not attributable only to this universal factor but also has to be due to a language-specific structural one. The Spanish group, in general, prefers the second segment of the cluster, i.e. the more sonorous one, in onset clusters, and the German children prefer the first segment of the cluster, i.e. the less sonorous one, in onset clusters, but the more sonorous in final clusters.

And in final position, the SHH is not at all valid. Thus, many languages like Greek, Japanese and certain dialects of Spanish disallow stops in final position. In this respect, Standard German should be mentioned, too. Instead of an allophonic [k], in the syllable coda the continuant [ç] can be produced, as in *erledigt* [ʔɛʁleːdiçt] or *fleißig* [flajsiç]. In Iberian Spanish the syllable-final plosive is articulated as a fricative in some dialects, as in *apto* or *acto*, pronounced [aθto]. This synchronic evidence has been confirmed by historical evidence. According to Iverson & Salmons (1992: 305f.) the reconstructed Proto-Indoeuropean language exhibits a general tendency to license segments with a higher sonority ranking in the syllable coda than in the syllable onset. In accordance with this, stops are normally least expected in the coda, as argued by Bailey (1977: 162). This can be generalized in a preference for the coda as a secondary licenser to favour the more sonorous segments. On the basis of synchronic as well as diachronic evidence it can be concluded that universally the coda position licenses more sonorous elements, so that sonorants are less marked than obstruents, and for obstruents [+cont] is the unmarked value for manner in the coda. This may be referred to as the SONORITY LICENSING PRINCIPLE OF THE CODA (SLPC). The validity of this principle is supported by the German data, because in coda target clusters of sonorant plus obstruent, the sonorant is selected in 43 out of 47 cases (91·5%), whereas the obstruent is selected only four times; and in coda target clusters of fricative plus stop the fricative is selected in 24 out of 25 cases (96%), whereas the stop is selected only once (see Table 4*b*).

Regarding medial cluster production, our data show that Spanish children always select the second segment regardless of sonority, whereas the German data show mixed results. Here, neither the SHH nor the SLPC offers an explanation. In target...VC1.C2V...structures, the selection should be in favour of C2, because of the PARALLEL SYLLABLE STRUCTURE CONSTRAINT (PSSC), first proposed by Boomer & Laver (1968: 126) in the domain of speech errors. (See Berg, 1992, who extends it to child language.) According to the PSSC, the accessibility of a segment to fill a certain syllabic constituent depends upon its filling the same constituent in the target form. That is, the child should select the onset C2, in order to fill the onset of the CV syllable.

To summarize, the explanation relating to the child's inventory is only applicable to those cases in which the choice of one of the target segments of the cluster is determined by the non-existence of the other segment in the child's phonology. But it does not make any predictions in those cases in which both segments of a target cluster have already been acquired. The SHH cannot explain those cases in which the marked member of a cluster is produced, while the default is deleted. Sonority can be taken into consideration, but it cannot be the only mechanism responsible for reduction. Directionality must be taken into consideration, too. Crucially, directionality offers a unitary explanation, whereas the two sonority principles, SHH and SLPC, at best have to share their fields of influence, and at worst they fail. That is, in general, in onset and medial clusters, the unpredictable choice of the more sonorous segment always corresponds to C1 in German and to C2 in Spanish. Violations of SHH are explainable by means of directionality. In German coda clusters, although no cross-language comparison is possible, directionality as well as SLPC always result in the choice of C1. Directionality is thus the only unitary explanation able to account for the segmental choice in initial, medial and final position. In short, besides taking universal factors such as the SHH and the SLPC into consideration, it has to be assumed that children syllabify the target word from left to right or from right to left, depending on the target language, and that this direction of syllabification leads the German and the Spanish children to choose different segments, C1 in German and C2 in Spanish.

Even though the preferences are clear, they are not exhibited to the same degree by all children. These differences are explainable by varying individual experiences with the target languages (see the discussion on directionality in German and Spanish, below). In this sense, in onset position Miguel and José do not show the same marked preference for C2 that the other two children show, or that they themselves manifest in medial position. Apparently, they turn to directionality later than María and Juan.

Syllable structure in early child phonology

As briefly discussed in the Introduction, young children's syllabic structure begins with a minimal flat structure, corresponding to the core syllable, and develops further by means of parameter setting, resulting in the branching of syllabic constituents, i.e. in structure complexity. This has been shown in Fig. 1, using the N-bar model (Levin, 1985). The rhyme parameter is the first one to be activated, so only one prevocalic position and one postvocalic position are available.

In current research, two models have been proposed to handle syllabification. Syllabic schemes are either derived by means of rules or are represented as templates at all levels of phonological derivation. The rule account would imply that, starting from the nucleus, we have to associate to the left in order to build the onset. But there is no evidence for the acquisition of such rules. We claim that there is a fundamental reason to reject a rule account: children prefer CV syllables, i.e. the syllable type characterized as universal. However, universal phenomena should not appear as the result of derivation, but as primes. The mere existence of a rule would also imply the possibility of not applying it, which is not imaginable in the case of a universal phenomenon. Thus, the core syllable CV is not a matter of derivation and there is no reason to assume rule application in order to build it. A holistic treatment is more plausible for child phonology: it will take the form of templates in which the structural tier is hierarchically connected with the (sub)syllabic constituents through all stages of the derivation.

If, in adult phonology as well as in child phonology, templates rather than rules are an adequate device for the representation of syllables (Itô, 1989; Noske, 1993), directionality can be made responsible for the syllabification of the segments. Directionality is subject to parameterization. Syllabification takes place by means of the left-to-right or the right-to-left association of the segments with the canonical syllable scheme. The parameter of directionality determines which of the two segments of the adult cluster is selected to associate with the corresponding syllabic constituent of the child's phonological entry of the word.

Syllabification in German and Spanish

In order to set the directionality parameter, the child needs positive evidence in the target language. A brief discussion of some delimited aspects of syllabification in the adult Spanish and German models will help elucidate the evidence available to the child. It will be assumed here, too, that the representation of syllable structure adopts the form of templates.

As has often been observed (Harris, 1983, 1986; Crowhurst, 1992: 236), Spanish has a productive [e]-epenthesis rule to syllabify those word initial C positions lexically which, otherwise, would be extrasyllabic (e.g. *escribir* [eskɾi'βiɾ] vs. *inscribir* [inskɾi'βiɾ], *Eslovenia* [eslo'βenja] vs. *Yugoslavia* [juɣos'laβja]). The fact that the vowel is inserted on the left side from [s] is a genuine sign for syllabification from right to left. There are no cases where the vowel is added after [s] as in *[sekri'βiɾ], *[selo'βenja], which would actually be in accordance with the onset maximization of Spanish, were it not for directionality. This process of syllabification is in accordance with Itô (1989: 231f.), who assumes that underlyingly [s] is associated with the syllable node. The segment [s] occupies the nucleus position in the N-bar model adopted here (see Harris, 1983: 29, as well, for a rule-based analysis). Because in the phonetic output of the derivation no syllabic consonants are produced in Spanish, a vocalic position with the default vowel [e] is inserted in order to create a well-formed syllable. The vowel is inserted before the consonant to be syllabified, which shows that the direction of association runs from right to left. This derivation is represented in Fig. 7.

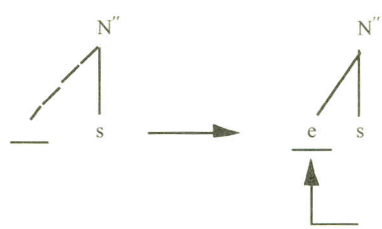

Fig. 7. The epenthesis rule in Spanish.

Another convincing argument for the leftwards syllabification of consonants is the maximization of onsets in Spanish (Crowhurst 1992: 237). In *iglesia* [i.'ɣle.sja] 'church' the [g] and the [s] are syllabified to the onsets and not to the preceding codas: *[iɣ.'le.sja] and *[i.'ɣles.ja] are absolutely ungrammatical. Consequently, in Spanish the creation of the onset occurs before that of the coda (Hualde, 1992: 482f.), which is the consequence of right to left syllabification, in a model such as Itô's.

An analysis of morphologically complex words, such as compounds and words with prefixes, manifests this same maximization of onsets: *col* and *flor* results in [ko.li.'flor] 'cauliflower', *pez* and *espada* results in [pe.θes.'pa.ða] 'sword fish'. The prefix *in* with a stem beginning in a vowel results in syllabifications such as in *inactivo* [i.nak.'ti.βo] 'inactive', *inacabado* [i.na.ka.'βa.ðo] 'unfinished'. Resyllabification, by which the coda consonant becomes the onset of the following syllable, if this would otherwise begin with a vowel, takes place over larger syntactic domains, as well: *los hombres* [lo.'som.bres] 'the men', *van y vienen* [ba.ni.'βje.nen] '(they) come and go' (Harris, 1983: 43f.; Hualde, 1992: 485f.).

In contrast, German exhibits signs of coda maximization at the phonetic surface. Stress in German is always assigned to a heavy syllable (Giegerich, 1992: 164f.). The coda in a stressed syllable with a short vowel has to be filled, even if the consonant in question has already been syllabified with the onset of the following syllable, as in *Mitte* ['mɪt̩ə] 'centre', which leads to ambisyllabic consonants. Coda maximization provides evidence for left-to-right syllabification (see Itô, 1989).

German exhibits other signs of left-to-right syllabification, too, in compounds or in prefixed verbs or adjectives. Cases of coda realization, in which the syllable-final consonant is not resyllabified to the onset, occur in compounds and prefixed words. Even though the data have been analysed in different ways (Wiese, 1988: 88f.; Yu, 1992: 172f.), coda maximization takes place across compound boundaries and prefix-stem boundaries: in compounds like *Weltall* /vɛlt.al/ 'universe', *Osterei* /ostɛʀ.aj/ 'Easter egg' or *Kraftakt* /kʀaft.akt/ 'strong-man act', the consonants of the initial syllable codas are not resyllabified with the following vowels. The same is true for prefixed words, in which the final consonant of the prefix is not resyllabified with the following vowel of the stem, as in *inaktiv* /in.aktiv/ 'inactive', *entehren* /ɛnt.eːʀən/ 'dishonour'. These facts can be easily explained in terms of left-to-right syllabification.

The different treatment given to intervocalic consonants in the target languages, Spanish and German, is also supported by data on second language acquisition. It is not uncommon for German speakers learning Spanish to pronounce a word like *biblioteca* 'library' as [bip.ljo.te.ka], with devoicing of syllable final [b]; notice that in Spanish it is pronounced [bi.βljo.te.ka], with spirantization of the onset [b] of the second syllable.

In the domain of speech perception, some evidence can be adduced for the right-to-left directionality in Spanish, although here the evidence is not unequivocal. In a series of experiments carried out with French and with Spanish subjects (Pallier *et al.* 1993), a noticeable difference appeared between the two language groups. The subjects were given bisyllabic words and had to detect a target phoneme appearing either as the coda of the first syllable or as the onset of the second syllable. The subjects in each language group were divided into a coda group and an onset group, and became coda lists or onset lists depending on the group they belonged to; the words of the list were 'inductors', i.e. they were intended to 'induce subjects to attend to the target in a precise syllabic position' (Pallier *et al.* 1993: 376). Subjects in both language groups detected a segment much faster at the onset than at the coda, if they belonged to the onset group. Interestingly, the Spanish subjects in the coda group needed the same amount of time to detect a segment at the coda and at the onset, whereas the French subjects of the coda group needed longer to detect onsets than codas. Pallier *et al.* (1993: 380) point to the 'important advantage for targets in onset versus targets in coda for Spanish but not for French'. A complementary reading of these results is also possible: the Spanish subjects in the coda group were just being reinforced in their normal syllabification from right to left, so that detecting an onset did not take any longer than detecting a coda, because of their tendency to scan from right to left. French subjects, on the other hand, supposing that in French syllabification is from left to right, could detect a coda faster than the following onset. Another similar experiment done at higher speed gave parallel results. And an additional experiment done only with Spanish subjects using nonsense words, in order to avoid possible semantic priming effects, revealed that 'subjects of the coda group responded faster than subjects of the onset group' (Pallier *et al.* 1993: 384). Again, being induced to process codas before onsets reinforces the right-to-left directionality of the Spanish subjects and leads to faster processing times.

In view of all the evidence presented, we can safely assume that the German children are exposed to data exhibiting signs of coda maximization and left-to-right syllabification, whereas the Spanish children are exposed to data exhibiting onset maximization and right-to-left syllabification. Target-language evidence favours the setting of the directionality parameter from left to right in German and from right to left in Spanish. The target data are robust, but not fully unequivocal, so that different individual experience with the available data might lead particular children to undertake parameter setting at different paces. This has been discussed above in relation to onset clusters in the Spanish group, where some ambivalent results were found.

Underlying representations

How the underlying segmental form is represented in the child's phonological system (UR) has been previously discussed in the literature on clusters (Spencer, 1986; Iverson & Wheeler, 1987; Chin & Dinnsen, 1992). According to these proposals, the segments of a target cluster are present in the lexical representation of the child's words and, underlyingly, both positions are available, but only one prevocalic and one postvocalic position are produced in the phonetic form. The monosegmental syllable onsets and codas are created by means of deletion of one of the two segments (Menn 1978: 161f.) or by means of not associating them with higher constituents (Spencer, 1986: 13; Iverson & Wheeler, 1987: 253; Chinn & Dinnsen, 1992:

280). Deletions imply that structure has to be built up first in order to be deleted afterwards. Such redundancies can be avoided by means of underspecification and failing of prosodic licensing, as proposed by Spencer (1986), Iverson & Wheeler (1987), and Chin & Dinnsen (1992). We thus adopt a model, similar to the one proposed by Iverson & Wheeler, in which the child's UR is related to the input form by some kind of filter, and the output form results from the association of phonological features to word templates defined in metrical terms.

We want to argue that the existence of one single segment in the output can only be explained by the assumption of ONE skeletal position underlyingly, because the assumption of two underlying C positions would allow for the association of one more consonantal segment and lead to the production of both target segments of the cluster. Given a single C position, the child must have a trigger at his/her disposal to select only one segment. After 1;9 there is an alternating production of one or two segments, due to the fact that the syllabic parameters, with their resulting branchings, are being set. Because up to that point there is only one prevocalic and one postvocalic position available, the segments not articulated are not associated with the immediate higher structure, i.e. with the C position. This implies that, although one position is in general available at the skeletal tier, both segments must be stored at the melodic tier.

Further evidence for such an assumption is provided by so-called coalescences (Chin & Dinnsen, 1992). In these cases the selected segment forms a natural class with both members of the cluster, as in *clown*, pronounced [dawn] (see Table 3*c*). Here, no directionality can be attributed to the association of skeleton and melody, since some of the feature specifications of both target segments are present in the child's produced segment. In [dawn] for *clown* the child's [d] is coronal like the target [l], and a stop like the target [k]. In these cases, the segment produced by the child combines features of both target segments. As Chin & Dinnsen argue, such a process reveals that the child has at least some knowledge of the feature composition of the target segments and that both segments are somehow stored in the lexical entry of the child. But, because only one position is available in the child skeletal tier, the coalesced segment is the result of associating a feature subset of each segment to this position (see also Beers, 1993, who investigates the development of clusters in Dutch).

If, as argued here, both segments are present in the child's lexical entry, then the selection of one segment must be directionally driven. In the lexical representation, the segments and the structural tier are at first not associated with each other. Which of the two segments is associated with the C position depends on directionality. The lexical form of a target cluster is represented in Fig. 8*a* for the association from left to right and in Fig. 8*b* for the association from right to left.

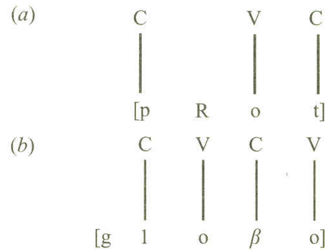

Fig. 8(*a*). Lexical representation of *Brot* (Johannes 1;10.27). (*b*) Lexical representation of *globo* (Miguel 1;10.18).

Interaction between principles and directionality

How are the results to be evaluated in the light of the theoretical background discussion? There are arguments for the syllabification from right to left in Spanish and from left to right in German. In contrast to these language-specific parameters, two universal aspects could PARTLY account for our results, too. The SHH can explain the preference for the less sonorous segments in onset clusters, and they do indeed appear in both language groups. Nevertheless, in the Spanish data the values show more fluctuation than in the German, and a certain dominance of C2, i.e. the more sonorous segment. The explanation is at hand: in the German data, the two factors, SHH and directionality, lead uniformly to the selection of C1. This is why the German group selects C1 without exception, exhibiting a stable developmental curve. The preference for C1 over C2 is statistically significant in the German data. In the Spanish data, even though the values for C2 are much higher than in German, the collective development as well as the individual values do not reveal a clear preference either for C1 or for C2, because the SHH leads to the selection of C1 and the right-to-left syllabification to the selection of C2; i.e. the two factors lead to contradictory results. Consequently, although there is a certain general preference for C2, the *t*-tests do not reveal any significant difference in favour of C2.

The interaction of universal principles and language-particular parameters is also manifested in medial clusters. There, the effects of the universal principle determining the PSSC interact with those of directionality, a language-specific parameter. Given a target sequence of VC1.C2V, at the acquisition stage in which a single skeletal C position is available, the PSSC predicts the production of V.C2V. Accordingly, the Spanish children, without exception, select C2 regardless of the sonority values (Tables 2 and 4*c*). In contrast, the German children manifest a certain tendency to select C1 along with C2. These data argue against the relevance of the PSSC in selecting one segment of a cluster. Then, given the PSSC, the mapping of the [CVC.CVC] target form onto the child's [CV.CV] syllable structure would lead us to expect nearly the same results in favour of C2, both in German and in Spanish. However, the dominance of C2 is more obvious in Spanish than in German: there are 88% C2 productions in the Spanish group but only 54% in the German one, resulting in a significant cross-language difference ($p < 0{\cdot}03$).

How can we account for this difference between both language groups in the way medial clusters are represented? Obviously, the relatively high C1 value in the German group is due to the additional application of the language specific left-to-right syllabification, which 'struggles' with the PSSC, giving contradictory results. In Spanish, right-to-left syllabification produces more uniform results. This observation also holds true individually. In the first and third cluster types of Table 4*c*, fluctuation is observable in the German data, whereas the Spanish children uniformly prefer C2. We have individual and collective evidence that directionality is relevant for the representation of clusters as a single consonant. The statistics give significant results in Spanish, but not in German, i.e. the preference for C2 over C1 is significant in Spanish ($p < 0{\cdot}007$), but not in German ($p < 0{\cdot}4$).

As regards the German coda, the SLCP accounts for the selection of the more sonorous segment, i.e. C1. The application of the left-to-right syllabification selects C1 as well. Both factors lead to a clear preference for C1 individually and developmentally, resulting in significantly higher values of C1 over C2 ($p < 0{\cdot}01$).

The interaction of the various principles and parameters with our results is summarized in Table 6. The Table makes explicit whether the principle

TABLE 6. *Summary of the results*

Syllable position	Universal principles	Language	Directionality of syllabification	Prediction	Results
Onset	SHH	German	Left–right	Same	C1 (s)
		Spanish	Right–left	Different	C2 (non-s)
Medial	PSSC	German	Left–right	Different	C2 (non-s)
		Spanish	Right–left	Same	C2 (s)
Final	SLPC	German	Left–right	Same	C1 (s)

relevant for a certain position and directionality of syllabification agree ('same') or whether they are in contradiction ('different'). The foregoing interpretations are clearly supported by the statistical results: only in those cases where the directionality and the universal principles select the same consonantal position, is the corresponding solution statistically significant ('s'). But if the principles select two different positions, the statistical results fail to reach significance ('non-s').

The collective development, which is in general characterized by parallel curves for C2 in German and in Spanish, confirms our conclusions (see Fig.

4). This parallel development is to be accounted for in terms of directionality and the universal principles stated above. Presumably the setting of the directionality parameter is universal and extends over a long time. The parameters switch at nearly the same time for the values, left–right in German and right–left in Spanish, which is evidenced by the parallel courses of the curves, with almost simultaneous fluctuations in both languages. The curve referring to onset clusters (Fig. 2) gives some support to the claim that, at least for Spanish, the directionality parameter is set at 1;9. This development is paralleled medially (Fig. 3), but there the great impact of the universal PSSC on syllabification is apparent, in the German as well as in the Spanish group.

Correct cluster production and parameterization

It has been argued earlier that coalescences provide evidence for the presence of the feature sets of both segments, and precisely for the absence of a second skeletal position. That is, two segments not being able to associate with one single position on the skeletal tier are reduced to one single segment. In our data, coalescence makes up only 4% of all reduced clusters for each child. In spite of their numerically limited value, coalescences can be interpreted as SPRINGBOARDS into the production of the two segments of a cluster. Accordingly, there is a correlation between the time at which a certain child begins to produce coalescences and the start of correct cluster production by this same child. For instance, two of the German children, Bernd and Marion, produce coalescences later than the other German children, at 1;11 and 1;10 respectively, and during the entire time span investigated, they do not produce any correct onset clusters. Johannes, who has the lowest percentage of correct onset clusters among the other German children, produces his first coalescences at 1;9, whereas Britta and Thomas produce some coalescences at 1;6 and begin correct cluster production at 1;10. In the Spanish group, only José produces any correct onset clusters, and he produces his first coalescences at 1;6, earlier than Miguel and Juan, whose coalescences begin at 1;8. At 1;4, María begins to produce coalescences AND correct medial clusters.

The chronological analysis of cluster production by means of two skeletal positions offers information on the development of the syllable and its branching. As stated at the beginning, clusters are represented differently according to their word position. An essential difference results from parameterization: the onset parameter is responsible for branching at the onset, and the rhyme, nucleus and coda parameters are responsible for branching at the rhyme, at the nucleus and at the coda, respectively.

Chronologically, the setting of the rhyme parameter takes place before that of the onset parameter (Kaye, 1989; Carreira, 1991). This acquisition sequence predicts that medial clusters belonging to the rhyme and non-branching onset should lead to correct productions earlier than onset clusters should. Indeed, the evaluation of the data for word medial position shows a significantly higher value for correct clusters there than at onset position ($p < 0.03$). This provides evidence that the rhyme parameter is set before the onset parameter.

In our data the production of correct coda clusters starts at 1;6, but the production of correct onset clusters starts later, at 1;10. Moreover, the values for coda clusters are greater and the curve is always higher than for the onset; the rising course of the coda curve, as well, begins one month earlier. This has to be seen as evidence that, in German, correct clusters are produced earlier in syllable final than in syllable initial position, although, as discussed earlier, the difference between final and onset correct clusters is not significant. Even if we take the quantitative measurements at face value, this does not necessarily entail that the coda branches before the onset does. As Fikkert (1994) has convincingly argued in regard to the acquisition of Dutch, at the early stages a syllable-final consonant, especially a sonorant, might belong to the nucleus and not to the coda of the syllable. This suggestion, if it is confirmed by our data, will entail that the nucleus parameter is set before the onset parameter. This conclusion on the earlier setting of the nucleus over the onset parameter is tentative and in need of further research. On the other hand, correct medial clusters are not significantly higher than correct coda clusters. This means that the values at syllable final position are more similar to the medial than to the initial position. Our data give evidence for the following acquisition hierarchy: CV > CVC > CVCC > CCVCC.

CONCLUSION

The investigation presented here has focused on the representation of target consonant clusters at the beginning stages of first language acquisition. First we analysed the reduced productions of these clusters, triggered by the availability of the core syllable structure CV and of CVC immediately thereafter. The syllabification mechanisms consist primarily of associating the melodic tier to the syllabic templates. At the stages in which syllabic constituents do not branch and one single C position is thus available, the selection of the segment which fills the single C position is influenced by three universal principles: the SHH is responsible for the choice at the onset, the SLCP at the coda, and the PSSC is relevant for medial clusters. These principles, applied on both segments stored in the underlying representation of a word, should lead to similar results in German and Spanish. Nevertheless, there is a preference for C1 in German and for C2 in Spanish. Such preferences are the result of directionality in the syllabification process which, as postulated here, is parameterized from left to right in German and from right to left in Spanish. Moreover, if the application of two single principles to a target cluster has convergent results, the development is stable and the individual values show a clear preference for the relevant position. This is reflected in statistically significant values. Otherwise, conflicting principles lead to divergent values and a fluctuating development, with non-significant values.

The directionality of syllabification, already applied by the children of our study, has a direct relationship to the acquisition of the syllable constituents; this is obvious in the investigation of the correct cluster productions. The German children begin the production of correct clusters earlier in final position than in initial position. This allows us to draw the tentative conclusion that rhyme branching is acquired before onset branching in German. That is, left-to-right syllabification enhances the mastering of coda clusters before that of onset clusters. In the case of the Spanish children, syllabification runs from right to left, and the onset clusters are acquired after the setting of the rhyme parameter. These results are in full agreement with Itô's thesis (1989: 220f.), according to which syllabification of one or more consonants from left to right results in coda maximization, while the association from right to left results in the maximization of the onset.

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