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1997

pages 278-283 of

Proceedings of the

GALA 97 conference on Language Acquisition

Edinburgh, April 4-6, 1997

Edited by Antonella Sorace, Caroline Heycock and Richard Shillcock

this is a draft version with almost identical pagination to the published copy

Longitudinal phonological and phonetic analyses of two cases of disordered /s/+stop cluster acquisition

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Abstract

There are two main types of change to a child's phonetic-phonological system which may go unperceived, untranscribed, and thus unanalysed. Instrumental phonetic analysis of child speech is needed to reveal such changes. One type of hidden developmental change is the subtle alteration of the phonetic realisation of a phonological category, and in this case, the changes are not evidence of phonological advancement. A more troublesome case for the field is that of 'covert contrast'. In this case, the child articulates a phonological contrast, but in such a way that contrastive pairs are still perceived as being homophonous. In transcription, the child is misrepresented because its phonological system is demonstrably more advanced than impressionistic transcriptions can possibly reveal. We discuss the relevance of such untranscribable phonetic development to theories of normal and pathological phonological acquisition, taking examples from a corpus of longitudinal cluster-acquisition data in subjects diagnosed as having phonological disorder.

1. Covert contrast

Before clusters are acquired, 'trick' and 'tick' may be homophones. At some point, the child begins to articulate /tr/ and /t/ differently, which provides proof that the phonological system of the child represents these contrastive structures differently. At some point, the different articulation of /tr/ and /t/ will be picked up in transcriptions of the child, and so transcription of child speech can provide evidence for those interested in the developmental changes in children's phonological systems. There is a logical requirement that the child needs to articulate contrasts in order for transcription to detect them, but there is no guarantee that transcribers will be able to detect a contrast from the moment that the child begins to articulate it. In fact, there may be a delay. This delay can be called 'covert contrast' (Scobbie, Gibbon, Hardcastle and Fletcher 1996, *in press*), because behaviour which is contrastive from the perspective of the speaker appears noncontrastive from the perspective of the listener (Figure 1).

While it appears, therefore, that children acquiring a phonological contrast can progress directly from incorrect, homophonous productions (perhaps with some phonological instability or lexical diffusion) to a perceivable full contrast, phonetic research indicates that phonological contrasts can be articulated in such an immature or inappropriate way that they cannot be perceived by adult listeners. Such listeners include those researching into child language acquisition.

Covert contrasts may be detected using instrumental phonetic analysis of child speech in order to reveal subtle differences which are difficult or impossible for adults, even trained phoneticians, to perceive.

A number of covert contrasts are reported in the literature, covering the acquisition of voice (e.g. Macken and Barton 1980; Scobbie, Gibbon, Hardcastle and Fletcher 1996; Weismer, Dinnsen and Elbert 1981), place (e.g. Gibbon 1990; Forrest, Weismer, Hodge, Dinnsen and Elbert 1990; Tyler, Edwards and Saxman 1990), manner (e.g. Kornfeld and Goehl 1974, Tyler 1995) and structure (e.g. Weismer 1984, Tyler 1995, Scobbie et al 1996). A variety of instrumental techniques have been employed, primarily acoustic, to demonstrate that untranscribed contrasts exist in the speech of children who are developing normally and in the speech of those with phonological disorder.

2. Development of phonetically mature contrast

When a phonological contrast in child speech is readily perceivable and transcribable, it might be thought that any further analysis is unimportant. On the contrary, subtle phonetic changes in 'already-acquired' parts of the phonology can be revealing.

Changes under the influence of the acquisition of new phonemes or structures would be of great interest. An example of such a knock-on effect would be a subtle, imperceptible change in the articulation of /t/ coinciding with the change in /st/ from a reduced [s] to a more adult-like [st]. Phonetic analysis (but not transcription) is able to reveal systematic patterns, not evident in, between the gestures underlying segments or clusters at all stages of development.

Of further interest is the acquisition of the phonetics-phonology interface in its own right: in particular, changes in the phonetic implementation of a phonological structure independent of changes in contrastiveness elsewhere in the system. The strong case of this is when language-particular secondary cues for a contrast are acquired *after* the basic ability to convey the contrast using a primary cue. To unravel some of the mysteries of phonetic implementation it will be necessary to study transcriptionally ‘correct’ but phonetically immature speech.

3. Noncontrastive phonetic development

It might be thought that the only purpose for phonetic development is to provide enough motor skill to convey the range of phonological contrasts required, and that once this level is reached, any further longitudinal changes have no developmental or general linguistic significance. This is untrue.

First, the phonetic maturation of young children deserves study in its own right as a component of language acquisition. For an example, see Smith (1978) on the timing control of children of 2;6-3 years old.

Second, in addition to expressing the large number of cues which are used to convey a phonological contrast, the child has to learn a language-specific paralinguistic system which has a wide range of sociolinguistic functions. This uses the same phonetic medium as the strictly phonological system (Scobbie, Turk and Hewlett 1997). The child therefore has to learn how to integrate contrastive and noncontrastive information.

4. The instrumental phonetic study of phonological and phonetic acquisition

The acquisition of phonological systems is normally analysed using transcriptions of children’s speech. Filtering children’s speech through even a trained adult’s perceptual apparatus can lead to misrepresentation of the child’s abilities at any given age. Such methodological problems can be overcome to an extent by using instrumental phonetic analysis to provide objective and direct measurement of the child’s speech, revealing covert contrast and patterns of immature contrast. Moreover, phonetic analysis enables us to study the acquisition of language particular phonetics, the acquisition of phonology, and their interaction, in addition to revealing facts relating solely to universal aspects of speech-motor development.

Figure 1 shows schematically how some of the stages in the acquisition of a phonological contrast (based on the stages of Macken & Barton 1980) might be realised in a case where there is rapid change from homophony to overshoot, followed by a more gradual approximation to the adult norm. The phonetic cue may be primary, for example VOT as a cue to initial stop /voice/, or secondary (often regarded as noncontrastive) such as vowel duration as a cue to final fricative /voice/. Other possible developmental schemas include a more gradual differentiation of contrasting elements, or the lack of any overshoot. Such other schemas (not shown due to limitations of space) also exhibit immature phonetic behaviour, whether it be immature contrast or covert contrast.

The implications for the study of developmental pathologies of speech are quite profound. If a child’s phonological system is intact, but their phonetic system is disordered, leading to homophony-laden speech, then the types of treatment that would be ap-

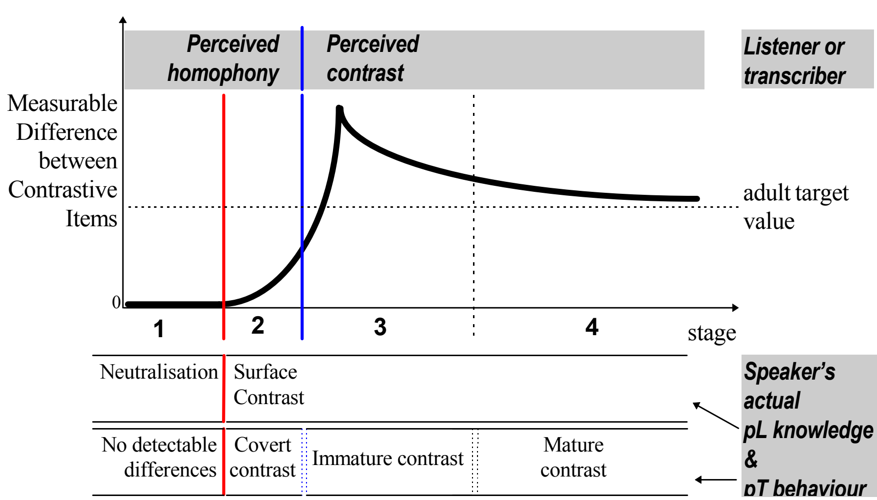

Figure 1: Schematic longitudinal phonetic measurement of a cue to a phonological contrast during the period of acquisition, showing continuous variation in the value of the cue: from homophony, through an overshoot, and finally to an asymptotic approximation to an adult norm. Discrete stages of phonological development are also indicated: the 2 stages which can be hypothesised on the basis of the instrumental evidence, and the 2 stages typically reported in impressionistic transcriptions. The mismatch between transcribed contrastiveness and instrumentally-detected contrastiveness defines the stage of covert contrast.

propriate are quite different to those which would be suitable for a child whose phonetic implementations are age-appropriate, but whose phonological system is rich with neutralisations (Gibbon and Scobbie 1997). Moreover, where covert contrasts have been detected, there is evidence that remediation is positively affected (Tyler, Edwards and Saxman 1990).

5. The QMC cluster acquisition database

The data we report in this paper is taken from the QMC Cluster Acquisition Database collected as part of an MRC-funded project: 'An instrumental investigation of consonant cluster acquisition in phonologically disordered and normally developing children' (Scobbie, Hardcastle, Fletcher and Gibbon 1995). This database has longitudinal acoustic data from a group of eight subjects with phonological disorder (initially aged 4;1 to 7;0) and cross-sectional control data from 12 normally-developing children aged 4;0-5;6. The children are speakers of Scottish English.

The heterogeneous group of children diagnosed as having a phonological disorder were recorded six times at approximately four month intervals. We elicited multiple instances of sentences of the form 'Give me spear please', in a series of ten games, all of which involved the child being given the appropriate picture for the elicited sentence. Thus the dialogue was relatively relaxed and naturalistic. No game involved rhyming or alliterating words. 'Spear' is one of 28 targets designed primarily to probe the acquisition of /s/+stop clusters. In this paper we discuss some durational results for /sp/, /st/, /sk/, /t/ and /d/, in three rime environments: /ir/, /or/, /ae/. The lexical items were: tie, dye, sty, spy, sky; tear, deer, steer, spear, skier; tore, door, store, score. (We also collected tokens of 'Spot', 'speak' and 'skate', but these short vowel rimes are not discussed here.) Six tokens of each target have been digitised.

6. Resolution of cluster reduction st > s

In this paper we focus on the acquisition of the cluster /st/ in two children with phonological disorder who reduce it to a fricative.[1] Subjects AE (7;0-8;8) and RS (5;4-6;9) impressionistically pronounce /st/ and /s/ as [s] in earlier sessions before resolving to [st] and [s] respectively. Unfortunately, data on the singleton /s/ was not included systematically in the database since reduction of a cluster to a fricative is relatively uncommon, so it is not possible to make any direct comparison between reduced /st/ and singleton /s/. Unequivocal evidence of covert contrast is not going to be possible for this contrast in these subjects.

[1] The poster on which this paper is based was also able to present a case of covert contrast (/d/ vs. /t/ and /d/ vs. /st/) which we discovered in another subject (DB) and details of this covert contrast are reported in depth elsewhere (Scobbie et al 1996, in press).

In the rest of this paper, we present phonological analyses of AE and RS, followed by a discussion of the instrumental measurements which were made, and then phonetic analyses of AE and RS. Traditionally, phonological analyses concentrate on the absolute presence or absence of phonological categories and the relationships between the actual system and the target system. Our phonological analyses adopt this approach but do not presuppose any particular theoretical framework.

7. Phonological analysis of AE

AE Session 1 (7;0): Underlying /s/ + stop clusters are realised as fricatives. This is due to fusion of place, to the preservation of the continuency specification, and to velar fronting in surface structure. Nonvelar stops are normal. /f/ and /s/ are normal. Homophony results due to the categorial identity of /sp/ and /f/, /st/ and /sk/, /st/ and /s/. Phonologically we could say that:

$$/sp/ \rightarrow /f/,\ /st/ \rightarrow /s/,\ /sk/ \rightarrow /s/.$$

AE Session 2 (7;6) and thereafter: velar fronting and cluster reduction are no longer evident. /s/+stop clusters and stops are normal.

8. Phonological analysis of RS

RS Sessions 1 (5;4) to 4 (6;5): Underlying /st/ is realised as [s] and appears homophonous with /s/, so phonologically, we could say /st/ → /s/. The clusters /sp/ and /sk/ are normal. Singleton stops are normal.

RS session 5 (6;9): all /s/ + stop clusters and the singleton stops are normal.

9. Durational analysis

The six tokens of each of the three target words for /st/ were digitised at 40,960Hz and spectrograms made using the KAY CSL system. n=18, except in the case of /sp/ n=12. Annotation points were added (see Figures 4 and 5) and the duration of the events they demarcate were measured. The events of interest here are as follows:

F: *friction.*
C: *closure*, noiseless, complete stop closure.
SC: *spirantised closure*, noisy, incomplete closure.
CC: *composite closure*, total stop closure, = **SC**+**C**.
OI: *obstruent interval*, = **F**+**CC**.
CC%OI: *closure as a % of the obstruent interval.*
SC%CC: *spirantised closure as a % of composite closure.*

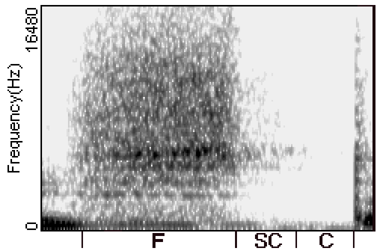

Figure 4: Partially spirantised /st/ AE, session 2

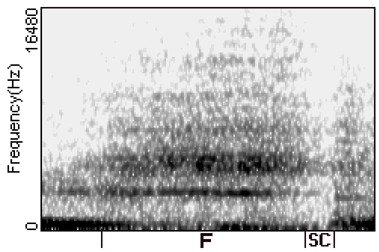

Figure 5. Totally spirantised /st/, RS session 5

Annotation points define the absolute duration of the fricative and stop components of the clusters, and the duration of spirantised (i.e. weak, noisy, transitional) closure between the fricative and stop proper. In addition, they give an indication of the relative contribution which the stop phase makes to the cluster (**CC%OI**) and the relative amount of spirantisation which is present during the stop phase (**SC%CC**). We regard a figure up to 25% for **SC%CC** as being relatively normal in child speech. It reflects an immature transition between fricative and stop.

Longitudinally, we can track these values before and after the 'instantaneous' acquisition of the clusters, to see the contribution of phonetic development to the phonological picture outlined above. AE was recorded over six session, and RS over five.

10. Phonetic analysis of AE

Figures 6 & 7 show the longitudinal development of the stop components of /sp/, /st/, /sk/ and of /t/ and /d/.

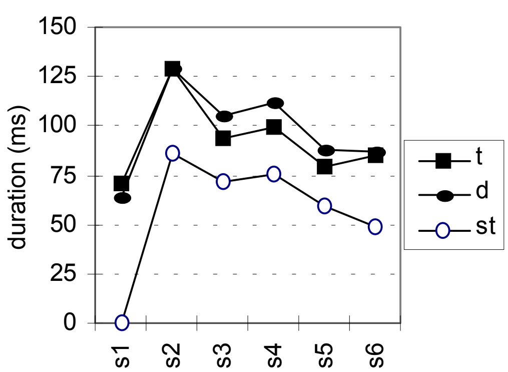

Figure 6: AE's **CC** for coronals

From Figure 6 we can see that in session 1 /st/ has 0ms of closure, but that in session 2, /st/ gains a stop component. In general, the duration of the stop component gets less as the child matures, but in session 2, the duration of /t/ and /d/ *doubles*, increasing by about 60ms, probably under the influence of the newly acquired stop in /st/. It is normal for /t/ and /d/ to be longer than the stop in /st/, and this relationship seems to have been achieved in session 2 by boosting the duration of /t/ and /d/.

Preliminary investigations suggest that velar and labial stop durations are also boosted. The singleton velar stops are longer than the stop in /sk/, but /sp/'s stop component is comparable to the singleton labials. Also relevant is the fact that the cluster /tr/ and the affricate /tʃ/ were both transcribed as [tʃ] in sessions 1 and 2. Preliminary results indicate that the duration of the stop in /tr/, /dr/ and /tʃ/ *decreases* between sessions 1 and 2.

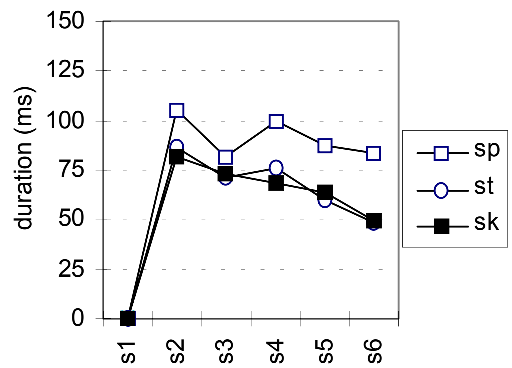

Figure 7: AE's **CC** for clusters

Comparison of /sp/, /st/ and /sk/ reveals that, grossly, the clusters behave homogeneously. The major difference is that /sp/'s stop component makes the greatest absolute (Figure 7) and relative (Figure 8) contribution to the obstruent interval.

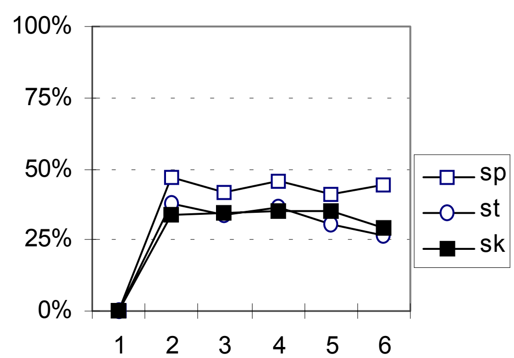

Figure 8: AE's **CC%OI**

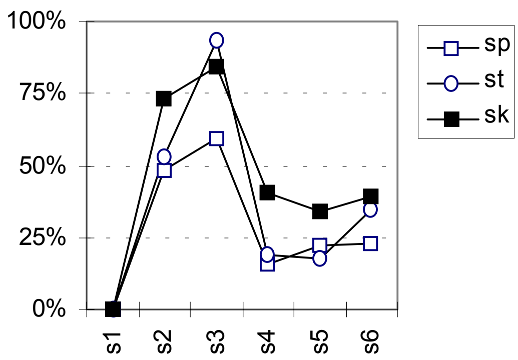

Figure 9: AE's **SC%CC**

Figure 9 presents a different picture. When [sp], [st], [sk] are first observed in session 2, their stop components are spirantised, by 49%, 53%, 73%, respectively, rising in session 3 to 60%, 93%, 85% respectively. In session 4, the levels of **SC%CC** fall back to a level consistent with being their due to the transition between fricative and stop (although /sk/'s velar stop remains about 1/3rd spirantised). The reason that the extremely spirantised /st/ is transcribed as [st] rather than [s] is probably due to its greater duration, to the fact that there is usually a stop burst (Figure 4), and because the distribution of /st/ tokens includes some clear examples of canonical [st].

This phonetically oriented analysis contains much more detail than section 7, but it also reveals *patterns* of development which a transcription based analysis misses. The acquisition of /sp/, /st/ and /sk/ *appears* to be complete by session 2. In fact we have seen:

(a) in sessions 2 and 3, clusters' stops are heavily spirantised, nearly reducing /st/ to [s] and /sk/ to [sx],

(b) in session 2 there is a large increase in the duration of the closure phases of /t/ and /d/.

Rather than positing a change to the phonological system between sessions 1 and 2, we could account for the cluster being acquired by supposing AE had somehow managed to change his motor implementation of stop closures in order to overcome his previous inability to articulate /sp/, /st/ and /sk/. If AE reinterpreted stops in this context by assigning greater duration to their closure gesture, the articulatory demands on AE would be less, enabling an acceptable cluster to be produced. The fine motor control of the clusters is still immature, however, especially in the case of the homorganic cluster /st/, which exhibits weakened stop closure for two sessions. Such blending is typical of homorganic clusters in adult casual speech (Catford 1977; Browman and Goldstein 1990).

11. Phonetic analysis of RS

Figures 10 and 11 show a gradual reduction in the stop closure duration (**CC**) of /t/, /d/, /sp/ and /sk/. /st/'s session 5 **CC** has an even shorter mean duration and is highly variable (Table 1). Consequently, and due to a slightly longer fricative than /sp/ or /sk/, /st/'s **CC%OI** is only 24% (Figure 12). Moreover, /st/'s stop is weak and variable (Figure 13, Table 2). In five cases /st/ **SC%CC** is 100% (Table 2), though it is still transcribed [st], for similar reasons to AE (Figure 5).

Session 5	mean	s.d.	Coeff-of-Variation	Range
/sp/ *n*=12	56	10	18%	46-80
/st/ *n*=18	41	19	46%	10-89
/sk/ *n*=18	71	17	24%	46-105

Table 1. RS's /sp/, /st/, /sk/ **CC** durations (ms)

Session 5	mean	s.d.	Range	# 100% cases
/sp/ *n*=12	13%	12%	0-25%	0
/st/ *n*=18	60%	31%	19-100%	5
/sk/ *n*=18	26%	29%	0-100%	2

Table 2. RS's /sp/, /st/, /sk/ **SC%CC**

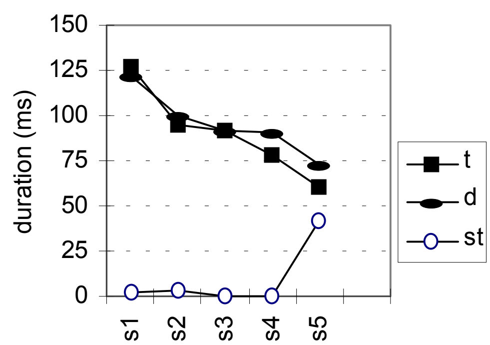

Figure 10: RS's **CC** for coronals

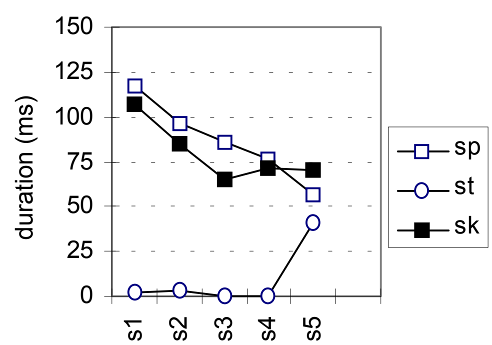

Figure 11: RS's **CC** for clusters

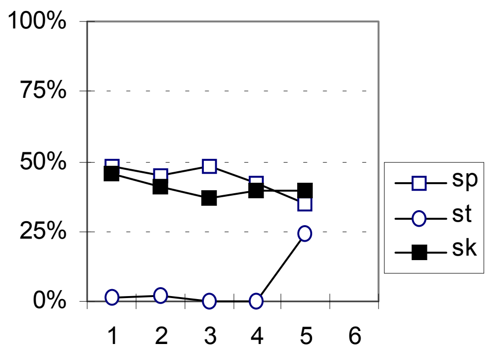

Figure 12: RS's **CC%OI**

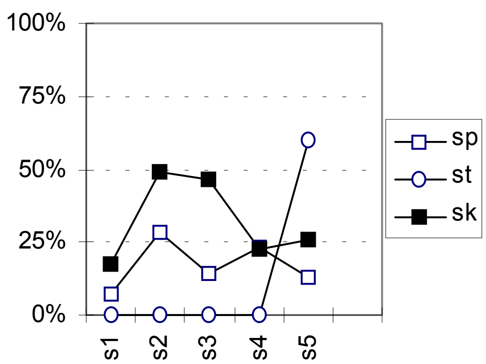

Figure 13: RS's **SC%CC**

The fact that it is only the homorganic /st/ in sessions 1-4 which is affected by cluster reduction suggests homorganic gestural blending with resultant spirantisation of the stop as a possible explanation. Phonetic analysis shows that in session 5, after acquisition is 'complete', the stop component of /st/ is extremely short (absolutely and relative to /sp/ and /sk/) and twice as weak as the stops earlier acquired /sp/ and /sk/ (Table 2). We hypothesise that RS's development can be characterised by a gradual reduction in gestural blending and would predict that later sessions would have shown further changes along these lines. Transcription therefore hides a continuum of development by positing a distinct 'before' and 'after'.

12. Concluding remarks

Is 'phonological' disorder a uniquely cognitive problem, or does it result from a combination of cognitive and speech-motor deficits, in the interface with phonetics? Transcription can be a barrier between speech and our understanding of it, but instrumental analysis can directly clarify both the phonological system and the fine-motor immaturities of the speaker.

The acquisition of a phonological contrast can appear to be abrupt from the perspective of the listener, but from the speaker's perspective, there are gradual and continuous developmental changes in the articulation of the phonological categories in question. Instrumental phonetic analysis can uncover this continuity in articulation, both by revealing covert contrasts and by uncovering the gradual and systematic development of the phonetics/phonology interface.

Acknowledgements

We gratefully acknowledge the support of MRC (G9117453) and ESRC (R000237135) and thank our subjects and their families, and the audience at GALA for comments on the poster version of this paper.

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