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Sonority and the unusual behaviour of /s/

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1 Introduction

A cross-linguistic examination of phonological behaviour generally supports the position that stops and fricatives form a single sonority class of obstruents (e.g., Clements, 1990). Among obstruents, however, /s/ stands out as exceptional. It often defies the phonotactic constraints that hold of other obstruents. It also commonly resists participating in processes that target or yield voiceless fricatives. From an acoustic perspective, /s/ differs from other obstruents in containing robust internal cues for place and manner of articulation (Wright, 2004). This ensures that it can be appropriately identified, regardless of where it appears in a string of segments, and makes it resistant to participating in change.

Most of the literature on the unusual behaviour of /s/ has focused on Indo-European languages. One unexpected construction that many of these languages share is word-initial /s/+consonant (sC) clusters, so much of the literature has motivated analyses for /s/ in this context. However, sC clusters are sometimes considered to be an Indo-European anomaly, which leads us to question whether non-Indo-European languages have sC clusters displaying similar properties; and, more generally, whether /s/ behaves in unusual ways outside of Indo-European and, if so, how this should be formally expressed.

These questions will be addressed by examining /s/ in the syllabification systems of three unrelated languages: Acoma (Keres) (Miller, 1965), Blackfoot (Algonquian) (Frantz, 2009) and Ōgami (Ryukyuan) (Pellard, 2009). In all three, /s/ functions unusually, but the patterns it displays differ from language to language and are, to a great extent, unlike what has been observed for Indo-European. We will thus conclude that /s/ patterns outside of its sonority class in typologically diverse languages, although the behaviour that it displays is not necessarily the same in all languages. This leads to the difficult challenge of finding a unified representation for /s/. Although we will conclude that this is not possible, we will nevertheless show that the diverse phonotactic behaviour that /s/ displays can be analysed in terms of ordinary syllable constituents if an abstract view of the syllable is adopted.

2 /s/ in Indo-European

We first demonstrate some of the ways that /s/ patterns outside the sonority class of obstruents in Indo-European languages, beginning with phonotactics.

2.1 A preliminary look at phonotactics

A cross-linguistic examination of the constraints holding of word-initial clusters reveals that obstruents must typically be followed by segments of higher sonority, while /s/ is not restricted in this way.[1] Table 1 illustrates this for English and Italian respectively: stops and fricatives must be followed by approximants in English and by liquids in Italian, while /s/ can additionally be followed by stops and nasals in both languages, as well as by fricatives in Italian.[2,3]

Table 1. Word-initial clusters in English and Italian.

English:			Italian:		
Stop-initial:			Stop-initial:		
[pl]/[bl]		[kl]/[gl]	[pl]/[bl]		[kl]/[gl]
[pr]/br]	[tr]/[dr]	[kr]/[gr]	[pr]/[br]	[tr]/[dr]	[kr]/[gr]
	[tw]/[dw]	[kw]			
Fricative-initial:			Fricative-initial:		
[fl]			[fl]		
[fr]	[θr]		[fr]		
	[θw]				
/s/-initial:			/s/-initial:		
[sp]	[st]	[sk]	[sp]/[zb]	[st]/[zd]	[sk]/[zg]
			[sf]/[zv]		
[sm]	[sn]		[zm]	[zn]	
	[sl]			[zl]	
	[ʃr]				
[sw]					

The observation that obstruent-initial clusters must rise in sonority is consistent with the view that stops and fricatives are optimally located in positions that maximise their perceptibility (Wright, 2004): they are identified most reliably when followed by sonorants. /s/, by contrast, is not bound to the segment that follows it in the same way. It contains robust cues for place and manner, which ensures that it can be appropriately identified regardless of where it appears. Perceptibility, then, is one element required to explain why /s/ falls outside its sonority class and seemingly has a freer distribution than other obstruents in initial clusters.

2.2 The behaviour of /s/ in phonological processes

If the acoustic properties of /s/ are partly responsible for its behaviour, the same cues which ensure that it can be appropriately identified should also make it resistant to participating in change. Specifically, there should be languages where alternations between stops and fricatives leave /s/ untouched. Such processes are attested in Indo-European. Consider, for example, Grimm's Law, which describes several systematic changes in consonants that took place between Proto-Indo-European and Proto-Germanic. The change of concern is that where Proto-Indo-European voiceless stops weakened to voiceless fricatives: $p > \Phi$, $t > \theta$, $k > x$. Notably, t weakened to θ, not to s.

Surprisingly, though, weakening does commonly target /s/ in Indo-European, as observed in the historical development of Greek, Sanskrit and Armenian, and in the synchronic grammars of Gaelic and Ibero-Romance languages. For example, Andalusian Spanish as well as Caribbean and coastal dialects of Latin American Spanish all exhibit lenition in word-final position, where /s/ is realised as [s]~[h]~Ø (e.g., Alcina Franch and Blecua, 1975; Lipski, 1994). /s/ lenition is unexpected, as the place and manner (i.e., stridency) of /s/ should be readily recoverable from the acoustic signal, such that /s/ is reliably perceived as distinct from zero. In searching for an explanation of this unexpected behaviour, we probe the phonetic properties of /s/ in leniting varieties of European Spanish.

Experimental work undertaken by Romero (1995) shows that Andalusian /s/ is articulated differently from Castilian /s/. In the latter variety, /s/ is a strident apico-alveolar fricative, which contrasts with non-strident lamino-dental /θ/. Andalusian has neutralised this contrast in favour of laminal /s/, which has a variable constriction location. Romero shows that, when compared to Castilian, Andalusian laminal /s/ involves a reduction of gestural magnitude, which he further proposes was the trigger for lenition in this dialect. When coupled with Shadle (1991), who observes that apico-alveolar tongue posture is optimal for achieving the narrow constriction required for strident /s/, we can conclude that Andalusian /s/ is low in stridency, thereby approaching theta.

Thus far, we have seen that the perceptual properties of /s/ enable it to pattern differently from other consonants in its sonority class. On one hand, high strident /s/ can have an unusual phonotactic distribution: in initial position, for example, it does not depend on the presence of a following sonorant to be reliably identified. Low strident /s/, on the other hand, can be singled out for lenition. At this point, we must address whether the diverse behaviour of /s/ can be explained solely by its perceptual properties or whether these work in concert with structural properties. To address this question, we return to the phonotactic constraints that hold of initial sC clusters. As we will see, although the perceptual properties of strident /s/ can account for why /s/ can appear before stops in such clusters, it cannot account for the distributional constraints that hold of sC clusters across Indo-European.

2.3 Phonotactics revisited

In section 2.1, we observed that although the phonotactic constraints holding of word-initial clusters reveal that obstruents must typically be followed by segments of higher sonority, data from Indo-European demonstrate that /s/-initial clusters need not respect this constraint. Table 1 showed that sC clusters are quite free in English and Italian in terms of the range of sonority profiles they exhibit. Indeed, when viewed from the perspective of obstruent-initial clusters, the patterns in these two languages suggest that it is before stops, as well as before nasals, that /s/ is unusual, as these are the only clusters with a flat or shallow rise in sonority.[4] In English, for example, /s/+liquid (*sly, shrill*) would appear to mirror obstruent+liquid (*fly, trill*). However, an examination of the patterns from French in Table 2 indicates otherwise: the only sC clusters it natively permits are /s/+stop.[5]

Table 2. Word-initial clusters French.

Stop-initial:		
[pl]/[bl]		[kl]/[ɡl]
[pʀ]/[bʀ]	[tʀ]/[dʀ]	[kʀ]/[ɡʀ]
Fricative-initial:		
[fl]	[fʀ]/[vʀ]	
/s/-initial:		
[sp]	[st]	[sk]
	*[s+sonorant	

A comparison of Tables 1 and 2 suggests that English and French fall at opposite ends of the spectrum regarding the range of profiles attested for sC clusters. Table 3 reveals that this is indeed the case: Indo-European languages that allow sC fall on a continuum such that languages that permit /s/+rhotic also permit /s/+lateral; languages that permit /s/+lateral also permit /s/+nasal; etc.[6,7] In short, as the sonority of the consonant following /s/ rises, the well-formedness of the cluster deteriorates (Goad, 2011, 2012).

Table 3. Word-initial sC clusters in Indo-European.

	Spanish, Brazilian Portuguese	French, Picard	Greek, Romansch	Italian, Dutch	English, Russian
/s/+stop	*	✓	✓	✓	✓
/s/+nasal	*	*	✓	✓	✓
/s/+lateral	*	*	*	✓	✓
/s/+rhotic	*	*	*	*	✓

Can the typology in Table 3 be predicted from the perceptual properties of /s/? To some extent, yes. First, the low stridency of /s/ in dialects of Spanish, as well as in Brazilian Portuguese (see Goad, in press), could in part account for the absence of sC clusters in these languages. Since all languages with sC clusters allow /s/+stop, reliably identifying weak /s/ in such clusters would be compromised by the absence of a sonorant following /s/. Not surprisingly, then, in both languages, sC-initial roots are repaired through prothesis when they surface word-initially, which enhances the perceptibility of weak /s/ (e.g., Spanish: [e̲spirar] 'to exhale'; cf. [a-spirar] 'to inhale, aspire to'; Brazilian Portuguese: [i̲stavɛw] 'stable', cf. [ĩ-stavɛw] 'unstable').

Second, the perceptual properties of strident /s/ can explain why /s/+stop is permitted in languages with sC clusters: as discussed earlier, /s/ has strong internal cues to place and manner, which means that it need not rely on an adjacent sonorant to be well-perceived.

In view of results like these, we may be tempted to conclude that a purely perceptual approach to the behaviour of /s/ can be provided. Indeed, in research that departs from the view that syllables are structurally represented, differences between /s/ and other obstruents are attibuted entirely to perceptual considerations (e.g., Fleischhacker, 2001): consonants are ordered to maximise their perceptibility and the acoustic properties of /s/ versus other obstruents account for their divergent behaviour (e.g., Wright, 2004). Such an approach, however, cannot explain why no language that allows sC forbids /s/+stop, nor can it explain why the well-formedness of sC worsens as the sonority of C increases (Goad, to appear). Answers to these questions emerge when perceptual considerations are coupled with structural considerations, as discussed below.

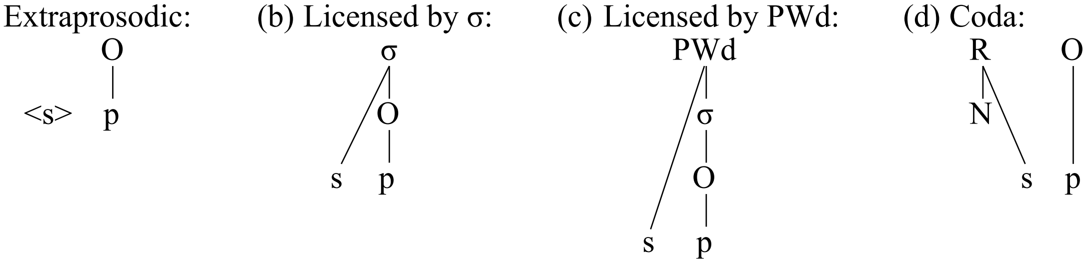
2.4 Representations

In research that assumes a structured view of the syllable, the different phonotactic generalisations of /s/- versus obstruent-initial clusters, as well as differences in their phonological behaviour, have led to the proposal that obstruent-initial clusters form branching onsets while sC clusters have /s/ located outside the onset constituent containing the following C, as shown in (1) (see Goad, 2011 for a recent review).

(1) (a) Obstruent-initial cluster: (b) sC cluster (minimal representation):

The representation in (1b) is the minimal one that holds for sC clusters. Various proposals for the organisation of /s/ have been forwarded in the literature, most commonly that /s/ is extraprosodic (e.g., Steriade, 1982): it does not belong to higher structure but is nevertheless protected from deletion; that /s/ is organised directly by the syllable (e.g., van der Hulst, 1984) or prosodic word (e.g., Goldsmith, 1990); or that /s/ is the coda (rhymal dependent) of an empty-headed syllable (following Kaye, 1992). Each of these options is sketched in (2). (The representation in (2d) is slightly simplified.)

(2) (a) Extraprosodic: (b) Licensed by σ: (c) Licensed by PWd: (d) Coda:



Of the options in (2), only (2d) correctly captures the phonotactic observations in Table 3 (Goad, 2012, to appear), specifically, that sC clusters should respect the constraints observed of coda+onset clusters, as detailed below. By contrast, the options in (2a-c), where /s/ is not organised by any type of sub-syllabic constituent, predict that /s/ and the consonant that follows it should not observe the same constraints that hold of other cluster types (branching onset, coda+onset, etc.).

We have shown that sC cluster well-formedness is tied to the relative sonority of the consonant following /s/. To examine how this mirrors the constraints that hold of word-medial coda+onset clusters, we turn to the Syllable Contact Law (Murray and Vennemann, 1983):

(3) Syllable Contact Law (SCL) (Murray and Vennemann, 1983:520):
The preference for a syllabic structure *A$B*, where *A* and *B* are marginal segments and *a* and *b* are the Consonantal Strength values of *A* and *B* respectively, increases with the value of *b* minus *a*.

Assuming the sonority scale in (4), higher consonantal strength values are assigned for consonants that are progressively lower in sonority.[8]

(4) Sonority scale:	obstruent (incl. /s/)	< nasal	< lateral	< rhotic
Consonantal strength:	4	3	2	1

If we examine word-medial heterosyllabic clusters with an obstruent in coda, the SCL correctly predicts that clusters with an increasingly steeper rise in sonority are more costly due to poor syllable contact:

(5) Word-internal position:				
Segmental profile:	Vp.tV >	Vp.nV >	Vp.lV >	Vp.rV
	Vs.tV >	Vs.nV >	Vs.lV >	Vs.rV
Syllable contact (*b*-*a*):	0	-1	-2	-3

In fact, word-medial clusters that steeply rise in sonority are optimally syllabified as complex onsets (✓V.plV/✓V.prV). If, however, this representation is never available for corresponding sC clusters (*V.slV/*V.srV), the coda+onset parse (Vs.lV/Vs.rV) will be the only option available (Goad, 2012).[9] In many languages, the steep rise in sonority observed for such clusters will not be permitted, excluding word-medial sC clusters of these shapes altogether. In French, for example, while steeply rising medial clusters are well-formed when they can form branching onsets (e.g., [a.tʀɛ] 'attraction', [ta.kle] 'to tackle'), parallel /s/-initial clusters are illicit (*[as.ʀɛ], *[tas.le]). When the sonority profile is flat, by contrast, the first consonant can be an obstruent or /s/, as the cluster will be represented as coda+onset ([ɔk.tav] 'octave', [kɔs.tal] 'coastal').

If sC clusters in initial position are similarly heterosyllabic, the same effect will be observed: while obstruent-initial clusters that rise in sonority will form branching onsets (e.g., [.tʀɛ] 'very', [.kle] 'key'), sC clusters will form coda+onset clusters and, therefore, their well-formedness will be sensitive to whether and how steeply the cluster rises in sonority. In French, only flat sonority sC is permitted ([s.taʒ] 'internship'; *[s.ʀɛ], *[s.le]), paralleling what is observed in medial position.

In short, languages draw the boundary between well- and ill-formed sC clusters at different points, depending on sonority slope. Although the poor syllable contact in steeply rising /s/-initial clusters is licit in some languages, like English (e.g., [s.lɛd] 'sled', [ʃ.rɛd] 'shred'), as the sonority profile of sC increases, the heterosyllabic parse worsens, making such clusters illicit in others, like French.

Unlike what has been discussed for French, though, the same language may draw the boundary at different places for initial and medial sC clusters. In English, for example, initial sC with C of all sonority profiles is observed (Table 3). Word-medially, however, /s/+sonorant is essentially unattested, as in French. In spite of this, the cross-linguistic options for medial sC reflect the typology in Table 3 for initial position: medial sC deteriorates as the sonority of C increases.

Because the sonority profiles for initial and medial sC may not perfectly align in any given language, ony may question whether they should truly be analysed in the same manner, as coda+onset. In view of this concern, we briefly examine differences in the voicing patterns of sC versus obstruent-initial clusters when sonority slope is held constant. Because voicing in coda is often dependent on the voicing value of following onsets, we should expect to find languages where /s/ in /s/+liquid clusters is voiced to [z], while voiceless obstruents in obstruent+liquid clusters are not, whether the cluster is located in initial or medial position. Consider Spanish. Although initial sC is not permitted in Spanish, in medial position, Spanish has the same profile as Dutch and Italian in Table 3. (6a) demonstrates that voicing agreement targets /s/ but not voiceless obstruents. This supports a coda+onset analysis for /sl/. Turning to Italian, recall that in initial position, sC clusters other than /s/+rhotic are permitted. (In medial position, Italian has the same profile as French.) As in Spanish, the Italian data in (6b) show that voicing agreement targets initial /s/ but not voiceless obstruents.

(6) (a) Spanish: medial position:

/sl/	[izla]		'island'
/fl/	[ʧifla],	*[ʧivla]	'whistle'
/kl/	[ʧikle],	*[ʧigle]	'chewing gum'

(b) Italian: initial position:

/sl/	[zlanʧo]		'dash, leap'
/fl/	[flanʤa],	*[vlanʤa]	'flange'
/pl/	[planʧa],	*[blanʧa]	'console'-N

These two languages support the view that /s/- and obstruent-initial clusters are syllabified differently and that sC form coda+onset clusters in both initial and medial position. If the coda+onset parse is the only one available for sC, these clusters will be sensitive both to the SCL, where clusters with a (steeply) rising sonority profile are disfavoured, as well as to coda voicing constraints.

3 Beyond Indo-European

As mentioned earlier, the literature on the unexpected distribution of /s/ has concentrated on Indo-European, with most attention focused on sC clusters. Because such clusters are sometimes viewed as an Indo-European accident, we turn now to look beyond Indo-European to examine whether /s/ patterns unusually in languages from other language families.

We consider the behaviour of /s/ clusters in the syllabification systems of three unrelated languages: Acoma (Keres) (Miller, 1965), Blackfoot (Algonquian) (Frantz, 2009) and Ōgami (Ryukyuan) (Pellard, 2009). As we will see, /s/ functions unexpectedly when compared with other obstruents, but the patterns it displays differ from language to language and are unlike what has been discussed for Indo-European. Although we will conclude that /s/ patterns outside its sonority class in genetically unrelated languages, because the behaviour it displays differs across languages, we are led to the difficult challenge of finding a unified representation for /s/. Although we will conclude that this is not possible, we will nevertheless show that the diverse phonotactic behaviour that /s/ displays can be analysed in terms of ordinary syllable constituents if an abstract view of the syllable is adopted: /s/ functions as the coda of an empty-headed syllable in Indo-European, as an onset followed by an empty nucleus in Acoma, and as nuclear in Blackfoot and Ōgami.

3.1 Acoma

We begin with Acoma, a Keres language spoken in New Mexico (Miller, 1965). As in Indo-European, /s/ patterns differently from other obstruents. At first glance, Acoma resembles French in that sC clusters are limited to /s/+occlusive. A closer look, however, reveals that a coda+onset analysis of sC is unwarranted, as there are no codas elsewhere in the language (in native words) (Miller, 1965). Coupled with other patterns of behaviour, namely the presence of a laryngeal contrast on the C following /s/ and an unusual type of allophony on the /s/ preceding C, we argue that sC clusters are not true clusters in Acoma but, instead, that an empty nucleus intervenes between /s/ and the following consonant (Goad, 2012). Consequently, unlike in Indo-European sC, where /s/ functions as a coda preceded by an empty nucleus, in Acoma, /s/ functions as an onset followed by an empty nucleus.

The data in (7) show that sC clusters, which are realised as [şC] or [ʃC] (see below), occur both initially and medially in Acoma (transcriptions have been converted into IPA). Medial clusters occur after both short (7b) and long vowels (7c). Although the former context might suggest a coda analysis for /s/, the latter casts doubt on this, as three position rhymes (i.e., VVs) in non-final position are cross-linguistically highly marked (e.g., Harris, 1994). Combined with the lack of codas in Acoma, an alternative solution for sC must be sought.

(7) (a)	#sC		(b)	VsC		(c)	VVsC	
	[şpúuná]	'pottery'		[j̓út͡s'işṗə́t^{h}ini]	'backbone'		[ẇi̓iʃṗi]	'cigarette'
	[ʃt͡ʃȧit͡s^{h}i]	'it is muddy'		[suʃt'á]	'I took water'		[ʔúuʃt͡ʃúut͡s^{h}i]	'drum'
	[şkút͡şúẇa]	'tadpole'		[ʔéşká]	'rawhide'		[ṡúuʃk^{h}i̓it͡s^{h}i]	'I am brave'

In searching for an appropriate analysis for Acoma, we provide two pieces of evidence that sC cannot form clusters in Acoma, that is, that /s/ and C are not truly adjacent in this language. The first piece of evidence is that the three-way laryngeal contrast present in the language is maintained after /s/, as shown in (8).

(8)	[ʔiʃtûwá]	'arrow'	[şku̓it^{h}aaʔa]	'he asked me'
	[ṁȧaʃt^{h}u]	'silver fox'	[şk^{h}úuj̓u]	'giant'
	[nȧaʃt'éṁi]	'starry eyes'	[şk'ət͡şə́əná]	'crumbs'

Languages where /s/+stop truly form clusters typically display one of two patterns: (i) such clusters are uniformly voiceless unaspirated, even if the language otherwise exhibits aspiration of voiceless stops (e.g., English); (ii) laryngeal contrasts are maintained after /s/, but /s/ itself undergoes assimilation to the following stop (e.g., European Portuguese), as observed in (6) for /s/+liquid. Illustrative data from English and European Portuguese appear in (9) and (10), respectively.

(9) English:

(a)	[t^{h}ɪl]	'till'	[dɪl]	'dill'	(b) [stɪl], *[st^{h}ɪl]	'still'
	[ək^{h}órd]	'accord'	[rəgárd]	'regard'	[əskórt], *[əsk^{h}órt]	'escort'-V

(10) European Portuguese (Mateus and d'Andrade, 2000:43):

(a) [ʃpásu]	'space'	(b) [ʒbíʀu]	'constable'
[ʃtaɾ]	'to be'	[ʒdɾúʃulɐ]	'dactyl'
[ʃkútɐ]	'listening'	[ʒgénɐ]	'strangulation'

To explain how the Acoma data in (8) cast doubt on a coda+onset analysis for sC, we must address why stops are uniformly unaspirated after /s/ in languages like English. We follow Iverson and Salmons' (1995) analysis which, itself, builds on Kim (1970). Kim proposes that aspiration is a consequence of the glottal width present in voiceless stops: in singleton stops, the vocal folds do not reach the adducted state required for voicing until after the release of the closure, which results in aspiration. As the glottis is open for the same interval of time in /s/+stop clusters, it will have narrowed by the point when the stop closure is released and, consequently, the onset of voicing will align with the release. To formally capture Kim's observations, Iverson and Salmons posit a single [spread glottis] feature shared between /s/ and the following stop. See (11a), which is adapted to the representation for sC clusters proposed here for Indo-European.

In view of this articulatorily-grounded account for the lack of aspiration after /s/ in English-like languages, it is surprising to find a language like Acoma, with contrastive aspiration after /s/, if /s/ and the following stop are truly adjacent. If, by contrast, an empty position interrupts the two consonants, this pattern is as expected, as each consonant would bear its own [SG] specification. Compare the representation for Acoma in (11b) with that for English in (11a).

(11) (a) English: [skai] 'sky' (b) Acoma: [ʂk^húuj̓u] 'giant'

Further support that sC clusters in Acoma are interrupted by an empty nucleus comes from an unusual pattern of /s/ allophony in the language, as mentioned earlier. Acoma exhibits a three-way contrast amongst sibilants before vowels: /s, ʃ, ʂ/. In sC clusters, however, sibilants are not contrastive: /s/ surfaces as [ʂ] before labial and velar stops followed by /u,ə,a/ and as [ʃ] before dental and palato-alveolar occlusives and before labial and velar stops followed by /i,e/.

In earlier work, I argued that [ʃ] and [ʂ] are derived from /s/ in sC clusters in Acoma, due to the low stridency of /s/ in this language (Goad, 2012). In section 2.3 above, we suggested that the absence of sC clusters in Spanish and Brazilian Portuguese could, in part, be attributed to the weakly strident /s/ in these languages. Another pattern that occurs in languages with low strident /s/ is that sC clusters are well-formed but a posterior sibilant replaces /s/. This occurs in German, for example, where the sibilant in sC clusters is realised as [ʃ]. German /s/ is quite [θ]-like: it involves greater constriction width, which results in a lowered spectral mean, than English /s/, more akin to English /θ/ (Fuchs and Toda, 2010). Given that all languages with sC clusters require /s/+stop, precisely the context where the perceptibilty of /s/ is most compromised, Goad (2012) proposes that German selects [ʃ] over [s] in such clusters, because of the [θ]-like quality of /s/ in this language.

Returning to Acoma, /s/ is described by Miller (1965) as dental (p. 7) and as followed by a "theta offglide" (p. 13). This is consistent with /s/ being weakly strident in this language, like /s/ in German, and in dialects of Spanish and Brazilian Portuguese. If /s/ were to surface as [s] in sC clusters, its perceptibility would be compromised, especially in Acoma where the only type of sC cluster permitted is /s/+occlusive. /s/ is thus realised as fully strident [ʂ] or [ʃ]; which posterior sibilant surfaces depends on the context: I suggest that [ʃ] results from assimilation and that [ʂ] appears in contexts where assimilation cannot apply. The two contexts where assimilation takes place, (i) before dental and palato-alveolar occlusives and (ii) before labial and velar stops followed by /i,e/, are exemplified in (12). We consider the feature involved to be [coronal] although, clearly, this needs to be examined further.

(12) (a)	Context (i):		(b) Context (ii):	
	[ʔiʃtûwá]	'arrow'	[hîuʃpéj̓u]	'cry baby'
	[ʃt͡ʃa̓it͡sʰi]	'it is muddy'	[s̓úuʃkʰ̓iit͡sʰi]	'I am brave'

Each of the assimilation contexts in (12), however, presents challenges. The challenge arising for assimilation context (i) is the following: if an empty nucleus interrupts /s/ and the consonant that follows, how can the feature involved spread from this consonant back to the preceding /s/? In other languages, place assimilation between consonants applies locally, that is, between string-adjacent consonants; indeed, it normally involves a coda assimilating to an immediately following onset, which may suggest that Acoma instead warrants a coda+onset analysis of sC clusters, as in Indo-European. However, even if a coda+onset analysis were proposed for sC in Acoma, the assimilation would apply non-locally in context (ii): the process is triggered by /i,e/, but it applies over top of labial and velar stops, as seen in (12b). Indeed, the pattern in (12b) would appear to pose a problem for any analysis of sC.

I suggest that an answer to the challenges posed by both assimilation contexts emerges from the representation for sC clusters I have provided for Acoma. Assimilation does not target /s/; rather, it targets the empty nucleus that follows /s/. Since the empty nucleus lacks all other features, however, the outcome of the spreading of [coronal] is perceived on the preceding sibilant. Importantly, the operation applies locally in both assimilation contexts. In context (i), it applies between string adjacent segments: the trigger is the coronal consonant in sC and the target is the empty nucleus that immediately precedes the trigger; see (13a). In context (ii), the trigger is the coronal vowel following the /s/+labial or /s/+velar cluster and the target is the empty nucleus that interrupts the cluster; the process thus applies locally, from vowel-to-vowel; see (13b).

(13) (a) Context (i): [ʔiʃtûwá] 'arrow'
…s Ø t û… → […ʃtû…]
[cor]

(b) Context (ii): [hîuʃpéj̓u] 'cry baby'
…s Ø p é… → […ʃpé…]
[cor]

To summarise, the patterns of behaviour observed in Acoma – the absence of codas, the presence of a laryngeal contrast after /s/, and the pattern of allophony observed for /s/ – reveal that an analysis where sC strings are treated as clusters is spurious; instead, an empty nucleus interrupts /s/ and the following C. Thus, in spite of some parallels with French, the coda+onset analysis of sC clusters is not warranted for Acoma. Moving outside of Indo-European has led to an alternative representation for sC clusters; clearly, they are not always entities of the same type.

One question that arises now is whether an empty nucleus between /s/ and the following consonant is ever warranted for sC in Indo-European. The answer is yes. /s/+fricative loanwords in English are a case in support of this. Recall from note 4 that Wright (2004:51) proposes that /s/+fricative is disfavoured across languages because there is not enough perceptual distance between the two members of the cluster to ensure appropriate identification of both consonants. This may suggest that, in some languages where such clusters exist, an empty nucleus interrupts the consonants. Indeed, in English, an alternative to the coda+onset analysis that otherwise holds for sC clusters in this language would reflect the fact that /s/+fricative is tolerated but not productive. Empirical support for this particular analysis comes from the observation that /s/+fricative loanwords display a voicing contrast: compare *[sf]ere* and *[sv]elte* (Goad, 2012). The latter example, where sharing of [voice] is not observed, in contrast to European Portuguese seen earlier in (10), is consistent with the presence of an empty nucleus between the two consonants.[10]

Thus far, we have seen that /s/ in sC clusters requires two different analyses: /s/ can be a coda preceded by empty nucleus; and /s/ can be an onset followed by empty nucleus. Although this approach to the analysis of sC requires an abstract view of the syllable – empty nuclei must be admitted – the result is that these clusters can be analysed using independently motivated syllable constituents (onset, coda), without recourse to additional machinery such as syllable appendices (see (2a-c)).

3.2 Blackfoot

We turn now to Blackfoot, an Algonquian language spoken in Alberta and Montana (Frantz, 2009). Like French and Acoma, word-initial sC clusters are limited to /s/+occlusive; see (14a). However, the forms in (14b), where sC clusters can begin with long /s/, already make this language appear unusual.[11]

(14) (a) [spát͡siko] 'sand' (D220)
[st͡síki] 'another' (D232)

(b) [sstamat͡sisa] 'Tether him to the stake!' (D229)
[sskánatsskiniwa] 'She has nice hair' (D22)

An appropriate analysis for Blackfoot becomes even more challenging when we consider the other contexts in which /s/ clusters can occur. The data in (15a) show that short and long /s/ can be flanked by consonants, while those in (15b-c) show that long and overlong /s/ can follow or precede a consonant, respectively:

(15) (a) [áakokstakiwa] 'She will count' (G79)
[itápsskonakiwaik͡si] '(My friend) shot at them' (G50)

(b) [kitssokáʔpssi] 'You are nice' (G23)
[ááhsssapiwa] 'He enjoyed watching' (D258)

(c) [íníkátoʔkatsiiwa anníísska óssska] 'he imitated his son-in-law' (D61)

A common element in works that have examined the unusual distribution of /s/ cross-linguistically is that none of them contest the position that /s/ is an obstruent. Like a vowel, however, and unlike other members of its sonority class, /s/ has strong internal cues, which ensure its perceptibility and identifiability, independent of context, as discussed earlier. We argue that the unusual distribution of /s/ in Blackfoot demonstrates that it functions as a strident vowel in this language (Goad and Shimada, 2014; building on earlier work by Derrick, 2006 and Denzer-King, 2009).[12] In short, then, in sC clusters in Indo-European languages, /s/ functions as a coda; in sC strings in Acoma, it functions as an onset; and in Blackfoot /s/ clusters, it functions as a vowel.

3.2.1 Syllabification

When 'unusual' /s/, exemplified in (14) and (15), is excluded from consideration, an examination of Blackfoot forms reveals that syllabification in this language is relatively straightforward, reflecting what is commonly observed in other languages: word-medial syllables generally require onsets, branching onsets are forbidden and coda+onset phonotactics are governed by constraints on sonority and place (Goad and Shimada (2014), building on Elfner (2006), Denzer-King (2009) and Frantz (2009)). Forms containing unusual /s/, by contrast, seem to freely violate these constraints. Contrary to appearance, it will be shown that if /s/ is analysed as a vocoid, we can arrive at an analysis of these complex patterns that respects the language's syllable structure constraints, that is, without treating /s/ as an appendix in any context (cf. Denzer-King, 2009) and without relaxing constraints on the structure of onsets (cf. Elfner, 2006).

Although unusual /s/ patterns as nuclear in Blackfoot, we espouse moraic theory (Hayes, 1989), as it is the only theory of syllabification that yields the flexibility needed for the various parses of /s/. We contend that unusual /s/ differs from other consonants, including 'ordinary' /s/, in moraicity and syllabification. Ordinary /s/ can be underlyingly non-moraic or monomoraic. Non-moraic /s/ is syllabified in onset (e.g., [póósa] 'cat' (G9)) or coda (e.g., [míínist͡si] 'berries' (G94)). Monomoraic /s/, when intervocalic, yields a geminate (e.g., [ik͡síssiwa] 'he is tough' (G5)). Unusual /s/ can also be underlyingly monomoraic, or bimoraic, but unlike intervocalic geminate /s/, it projects its own syllable, like a vowel. As we will see, this need not be stipulated: the context alone regulates the syllabification.

3.2.2 Monomoraic unusual /s/: medial position

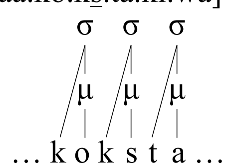
Monomoraic unusual /s/ yields syllables with short nuclear /s/. The data in (16) show the four ways that /s_μ/ can be parsed into syllable structure, depending on the quality of adjacent segments and, thus, constraints on their syllabification.

(16) Syllabification:

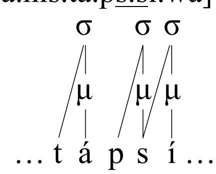
(a) nuc:	áa.ko.ks.ta.ki.wa	'She will count.' (G79)
(b) nuc+ons:	a.nis.tá.ps.sí.wa	'be-3:nonaffirmative' (G133)
(c) ons+nuc:	í.ss.ka	'pail' (G14)
(d) ons+nuc+ons:	áh.ss.sa.pi.wa	'He enjoyed watching' (D258)

Truncated structures are provided in (17). In all cases, /s_μ/ projects a syllable node, minimally yielding nuclear [s]. (17a) shows that /s_μ/ is realised as nuclear [s] alone when surrounded by consonants that must form onsets, in respect of syllabification constraints on place. When preceded by an onset consonant and followed by a vowel, as in (17b), $/s_{\mu}/$ is realised as nucleus+onset [ss]; the additional link creating an onset is forced by the requirement that medial syllables have onsets in Blackfoot. In (17c), where a vowel immediately precedes $/s_{\mu}/$, $/s_{\mu}/$ must become the onset of its own syllable, yielding an onset+nucleus parse, again due to the constraint against medial onsetless syllables. The structure in (17d) additionally has a vowel following $/s_{\mu}/$. Thus, the constraint against onsetless syllables comes into play twice, requiring $/s_{\mu}/$ to be syllabified as the onset of its own syllable as well as onset of the following syllable. (Note that [h] cannot be parsed in onset in Blackfoot.)

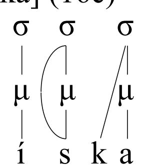
(17) (a) $/s_{\mu}/$ as nucleus:
[áa.ko.ks.ta.ki.wa] (16a)



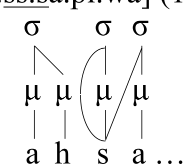
(b) $/s_{\mu}/$ as nucleus+onset:
[a.nis.tá.ps.sí.wa] (16b)



(c) $/s_{\mu}/$ as onset+nucleus:
[í.ss.ka] (16c)



(d) $/s_{\mu}/$ as onset+nucleus+onset:
[áh.ss.sa.pi.wa] (16d)



3.2.3 Bimoraic unusual /s/: medial position

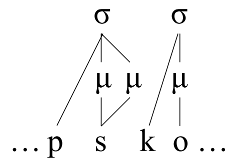
Bimoraic unusual /s/ yields syllables with long nuclear /s/. The data in (18) illustrate the three manners in which $/s_{\mu\mu}/$ can be parsed into syllables.

(18) Syllabification:

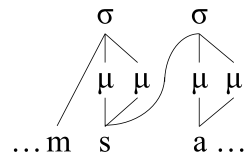
(a) nuc:	i.tá.pss.ko.na.ki.wai.ksi	'(My friend) shot at them' (G50)
(b) nuc+ons:	s.tá.mss.sáa.ko.noo.sa	'Try to recognize her!' (D166)
(c) ons+nuc:	ínikáto?katsiiwa anníisska ó.sss.ka	'he imitated his son-in-law' (D61)

Structures for these forms are provided below. In (19a), $/s_{\mu\mu}/$ is syllabified as nuclear [ss], parallel to (17a), as the immediately adjacent consonants must be parsed as onsets. The form in (19b) similarly parallels that in (17b): in addition to being parsed as a long nucleus, bimoraic /s/ must become the onset of the following syllable, to avoid a word-internal onsetless syllable. Finally, in (19c), this same constraint ensures that bimoraic /s/ is parsed as the onset of its own syllable, parallel to (17c).

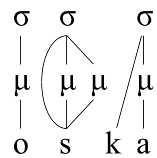
(19) (a) /$s_{\mu\mu}$/ as nucleus:
[i.tá.pss.ko.na.ki.wai.t͡si] (18a)



(b) /$s_{\mu\mu}$/ as nucleus+onset:
[s.tá.mss.sáa.ko.noo.sa] (18b)



(c) /s_{μ}/ as onset+nucleus:
[ó.sss.ka] (18c)



3.2.4 Unusual /s/: initial position

We turn finally to sC and ssC clusters in word-initial position. The forms below expand on those provided earlier. Note that initial sC (20a) and ssC (20b) respect the same constraints; this suggests that the same analysis should hold for both.

(20) (a)

[spát͡siko]	‘sand’ (D220)
[stámitapoot]	‘just go there!’ (D232)
[st͡síki]	‘another’ (D232)
[skiim]	‘female animal’ (D214)

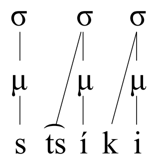
(b)

[sspitááwa]	‘He is tall’ (G23)
[sstamat͡sisa]	‘Tether him to the stake!’ (D229)
[sst͡sipísoohsit]	‘Punish (whip) yourself!’ (G105)
[sskánatsskiniwa]	‘She has nice hair’ (D22)
[ssk͡só?sat͡sisa]	‘Flesh a hide!’ (D225)

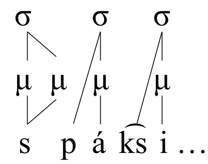
The first option to consider is whether initial sC and ssC clusters could be treated as coda+onset, as in Indo-European. This analysis is suspect, as medial sC clusters that are indisputably coda+onset are required to share place in Blackfoot (e.g., [istópiit] ‘Sit there!’ (F94)), while word-initial sC clusters are not (20a). More importantly, this analysis cannot be extended to initial ssC clusters in a principled way. Another option is Elfner’s (2006) proposal that initial sC clusters form complex onsets. This proposal is challenged by the observation that Blackfoot does not permit typical rising sonority complex onsets. In addition, we denied this possiblity for sC clusters in all languages (section 2.4). A third option is Denzer-King’s (2009) proposal that sC clusters are appendix-initial. This analysis cannot be extended to ssC, as appendices can only occur at the edges of morphological domains (Hayes, 1981; Harris, 1983), which would not hold of the medial consonant in ssC. Perhaps because of this, Denzer-King analyses ssC in a different manner, as bimoraic, an analysis we adopt.

Because we consider it important that the same analysis hold for both sC and ssC, we propose that [s] in initial sC is underlyingly monomoraic and [ss] in ssC underlyingly bimoraic, parallel to our analysis of word-internal unusual clusters. /s_{μ}/ and /$s_{\mu\mu}$/ both project a syllable, as the cluster cannot otherwise be syllabified:

(21) (a) Initial /s_{μ}/ as short nucleus: [st͡síki] (20a)



(b) Initial /$s_{\mu\mu}$/ as long nucleus: [sspák͡siʔk͡saahkoist͡si] (20b)



In sum, the account forwarded here, where Blackfoot /s/ is analysed as a vocoid, can straightforwardly capture a range of patterns that the language exhibits, in both initial and medial position. Importantly, allowing /s/ to be underlyingly (bi)moraic, thereby requiring it to project a syllable node, leads to the observed patterns without violating the language's constraints on syllabification: the context alone determines the parse.

3.3 Ōgami

Before concluding, we briefly address whether there are other languages like Blackfoot, where /s/ is fruitfully analysed as a vocoid. Ōgami (Southern Ryukyuan) appears to be such a language (Pellard, 2009). The forms in (22) show that fricatives, including /f/, can be syllabic in this language but, similar to Blackfoot, it seems that only /s/, which can be short or long, can appear between consonants, (22b).

(22) Ōgami (Pellard 2009:80):

(a) [s̩tɑ]	'underneath'	(b) [ps̩tu]	'person'
[f̩tɑi]	'forehead'	[ps̩:mɑ]	'day'

Beyond the parallels that hold with Blackfoot, Ōgami also draws attention to the fact that obstruents other than /s/ can function as vowels. Ōgami is not alone in this respect. In Imdlawm Tashlhiyt Berber (Dell and Elmedlaoui, 1985), both stops and fricatives can function as nuclear; in Niger-Congo and Sino-Tibetan languages, voiced coronal and labio-dental fricatives can function in this way (Faytak, 2012). We have seen, however, that /s/ is particularly conspicuous. Indeed, the comparison across languages has revealed that /s/ is atypical in several ways when judged against other members of its sonority class.

4 Conclusion

We have demonstrated some of the ways in which strident /s/ stands apart phonotactically from other members of its sonority class. This behaviour is grounded in the perceptual properties of /s/: its place and manner are readily recoverable from the acoustic signal, which ensures that it can be identified as distinct from other segments, regardless of the context in which it appears. At the same time, we have shown that the phonological patterning of /s/ cannot be reduced to perception. Indeed, perceptual considerations can be trumped by structural constraints. For example, the SCL favours /s/+stop over sC with rising sonority in Indo-European.

Determining the appropriate representation for /s/ in cluster contexts has proven to be challenging, as the patterns it displays differ across languages, which became apparent once we moved outside of Indo-European to examine typologically diverse languages. Nevertheless, although the range of behaviour that /s/ displays is diverse, we have shown that it can be analysed using ordinary syllable constituents if an abstract view of the syllable is adopted, one which admits both empty nuclei and strident nuclei: in cluster contexts, /s/ functions as the coda of an empty-headed syllable (Indo-European), as an onset followed by an empty nucleus (Acoma), and as nuclear (Blackfoot, Ōgami).

The possibility that sC clusters form branching onsets was rejected. We observed, though, that some languages admit /s/+liquid only, suggesting precisely this analysis. We leave examination of these languages, which we hypothesized contain non-strident /s/, to future research.

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[1] Henceforth, the terms 'obstruent' and 'fricative' will be used to refer to obstruents and fricatives other than /s/, unless otherwise noted.

[2] English [ʃr] is typically assumed to be derived from /sr/ (Clements and Keyser, 1983; Goldsmith, 1990); hence its inclusion in Table 1.

[3] Italian [zr] is absent from Table 1 because it is restricted to forms where a prefix boundary interrupts the cluster.

[4] Recall that Italian also permits /s/+fricative. I have ignored this here as the presence or absence of /s/+fricative does not follow the sonority continuum observed for sC in Table 3 below in the text: languages with /s/+sonorant do not necessarily have /s/+fricative. Wright (2004:51) proposes that /s/+fricative is disfavoured across languages as there is not enough perceptual distance between the two consonants.

[5] French also permits /s/+glide, but the glide is located in the nucleus (e.g., Kaye and Lowenstamm, 1984; Schane, 1989). Indeed, in Table 3 (below in text), we have excluded /s/+glide because glides in CGV strings can be syllabified in various ways across languages, each of which is subject to different constraints.

[6] Information on Picard was provided by Julie Auger (p.c.).

[7] /s/+nasal is only marginally acceptable in Greek.

[8] The sonority scale in (4) is that most commonly accepted in the literature (e.g., Clements, 1990), aside from the division drawn been types of liquids. The higher sonority of rhotics over laterals has been proposed by, for example, Selkirk (1984), Hall (1992) and Smith (2005) and is consistent with the relative well-formedness of /s/+rhotic versus /s/+lateral in Table 3.

[9] Ashley Farris-Trimble has informed me that a handful of understudied languages permit /s/+liquid as their only sC cluster. As the optimal branching onset across languages is obstruent+liquid (Clements, 1990), these /s/+liquid clusters may form branching onsets, counter to the proposal forwarded here. If this analysis can be supported, we speculate that /s/ may be low in stridency in these languages and, thus, unsuitable for involvement in true sC (coda+onset) clusters. /s/+liquid would thus be more akin to branching onset /θ/+liquid in these languages. Another possibility is that the liquid in /s/+liquid is nuclear in these languages, as proposed by Kaye (1985) for Vata. We leave detailed exploration of these languages to future research.

[10] In Sanskrit, a plain-aspirated contrast is found after /s/ (e.g., /stan/ 'thunder', /st^{h}ā/ 'to stand'). This may suggest the presence of an empty nucleus between the two consonants in this language as well. However, the phonology of Sanskrit sC is complex (see, e.g., Steriade, 1982, 1988); it would be premature to conclude that this contrast supports such an analysis at this time.

[11] Data are drawn from Frantz's (2009) grammar (G) and Frantz and Russell's (1995) dictionary (D). Numbers following G and D refer to page numbers in these sources. Transcriptions depart from these sources as follows: the addition of a ligature on what we consider to be affricates; the use of [ʔ] for glottal stop.

[12] Derrick (2006) states that Blackfoot /s/ "sometimes acts like a vowel"; Denzer-King (2009:51), proposes that "/s/ is inherently moraic, and can act as a syllable nucleus". Differences between our proposal and that of Denzer-King are spelt out in Goad and Shimada (2014).