

Segmental phonology in Ancient India?

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Abstract

The postulation of segmental units as real components of phonological competence is controversial, despite their widespread acceptance. One aspect of the controversy concerns the similarities between the units of segmental phonology and those of alphabetic writing: the historically and culturally contingent fact that Western society uses alphabetic writing may explain the primacy of segments in modern phonology. The ancient Indian tradition of phonological analysis has been claimed to exemplify a nonsegmental approach, reflecting their lack of influence from alphabetic writing. I show that the ancient Indian phonological tradition was fundamentally segmental, despite lacking any alphabetic influence. In ancient India, segmental units were identified as the basic units of analysis on the basis of purely linguistic considerations.*

Keywords: phonology, segments, phonemes, Indian linguistics, writing.

1 Introduction

In most linguistic and psychological accounts of language structure, phonetic or phonological segments are the fundamental units of analysis. Despite the modern recognition of the severe difficulties inherent in attempting to segment the speech stream, and of the importance of suprasegmental structure and features, phonetic or phonological segments remain a core element of most modern phonological analyses, and of most taught courses in phonology.

One issue concerning the reality of segments relates to alphabetic writing. For many authors (e.g. Port 2007, 2010a,b), it appears highly suspicious that a segmental approach to phonology developed and had such great success within an alphabetically literate culture. In fact, there is evidence that alphabetic literacy did contribute to the segmental direction of phonological theory. Granted that alphabetic writing is the product of contingent historical and cultural factors, the importance of segments in modern Western phonology may then reflect an undesirable intrusion of contingent material culture into our linguistic theorizing, undermining the field's aim of developing a valid model of human language.

The ancient Indian linguistic tradition developed in a nonalphabetic, and probably even nonliterate, culture. That tradition's approach to the analysis of speech sounds therefore has considerable potential bearing on whether the segmental bias of modern Western linguistics can be (partly or wholly) attributed to alphabetic literacy. The ancient Indian tradition is widely claimed to have been distinctly less segmental than our own, e.g. most prominently by Firth (1948), also Lüdtkke (1969), Mahulkar (1981). Here I re-examine this claim, and show rather that the ancient Indian tradition was fundamentally segmental. Crucially, this segmentalism cannot be attributed to alphabetic literacy. I argue that the development of segmental analysis in India was due to the particular properties of the language-specific phonological processes they were most interested in. Thus in ancient India, at least, the development of a segmental approach to phonology was based on purely linguistic considerations, and not biased by material culture. This does not necessarily mean that segmental units must be genuine units of language, but it does undermine the claim that Western segmentalism derives from alphabetic literacy.

2 Segments and phonemes in the West

Thus far I have avoided the term PHONEME, yet it is in this guise that segmental assumptions are most often encountered. The phoneme concept involves a number of assumptions over and above

the minimum required for a segmental analysis of speech, but for certain purposes phonetic segments and phonemes are interchangeable concepts (as e.g. for Fowler et al. 2016). The fundamental principle of a segmental analysis of speech is the following:

- (1) The segmental principle: the abstract phonological representation of a speech signal can be absolutely segmented into minimally distinctive, linearly sequential, units.

On this basis, given a minimal level of abstraction away from fine phonetic detail, we can identify three minimally distinctive segmental units in the word *bit*: [b], [ɪ], and [t̚]; the first two of these also occur in the word *bid*, the second two in *sit*. This type of unit I label PHONETIC SEGMENT or PHONE.

A further level of abstraction is required for a concept of phonemes. The single most important principle of a phonemic analysis is the concept of equivalence classes of speech sounds in complementary distribution:¹

- (2) The phoneme, principle A: the set of discrete abstract units required to analyse the phonology of a language (the ‘phonemes’ of that language) can be extracted from the (larger) set of phonetically distinct speech sounds (phonetic segments) of that language by taking one phoneme to represent one equivalence class of speech sounds which are phonetically similar and stand in complementary distribution to each other.

It is on this basis that phonologists can identify the [t̚] which occurs at the end of words like *bit* with the [tʰ] which occurs at the start of words like *tab*, treating both as positional variants, allophones, of a single phoneme /t/.

It follows from Occam’s Razor that the most parsimonious phonemic analysis will involve the smallest number of phonemes. For example, Firth (1936: 540–545) argues, against such phonemic parsimony, that initial consonant clusters like *st*, *str*, *sp*, *spl* etc. in English are units (‘group substituents’), and not mere sequences of /s/, /t/, /r/, /p/, /l/, etc. But standard phonemic approaches do segment these clusters in exactly this way, allowing us to posit fewer basic units, and thus producing a more parsimonious theory.

The second core principle of phonemic approaches involves the theoretical status of vowel and consonant segments:

- (3) The phoneme, principle B: on the level of phonemic analysis, vowels and consonants are fundamentally the same type of entity (viz. phonemes).

While almost every phonological analysis recognizes some distinction between vowels and consonants, on a purely phonemic analysis the sequence /ak/, for example, consists of two phonemes, just as the sequence /sk/ does, meaning that /a/ and /s/ stand in contrastive distribution. It is also significant that many phonemic analyses permit a single phoneme to be realised either as a vowel or as a consonant, e.g. a phoneme /i/ which surfaces as /y/ prevocally. If phonemes are potentially underspecified in respect of the vowel/consonant distinction, then there cannot be two fundamentally distinct types of entity, but only one (phonemes) with different possible realizations. It remains to be established whether the units of Indian phonological analysis were sufficiently abstract to be treated as equivalent to the modern notion of the phoneme. I will argue below that they are, but this is not crucial for the argument regarding segmentalism more broadly.

2.1 Problems with segments and phonemes

An early critic of segmentalism in phonology was J.R. Firth. Firth (1936: 536–539) argues that the evident utility of alphabetic writing is not the same as phonological accuracy, and that there is ‘a danger in... the abstract integration of “sounds” or “phonemes” or letters and signs in a mental scheme of ideas or in “the language as a whole”’. Firth (1936: 540–545) treats as significant the phonetic differences between apparent allophones in different contexts, and thereby rejects the above principle A of phoneme theory. Firth (1948) emphasizes the importance of syllables, and of suprasegmental features (‘prosodies’) which undermine the concept of a rigid segmentation of speech into successive units (the principle in 1 above).

Problems with assuming a segmental analysis of speech have been widely known for a long time. The acoustic signal is continuous, and it is widely held, following Liberman et al. (1967), that the acoustic cues for what are perceived as distinct segments are ‘intermixed in the sound stream to such an extent that definable segments of sound do not correspond to segments at the phoneme level’ (Liberman et al. 1967: 432). Moreover, the acoustic representations of the same segments in different contexts often have no shared features. So, the acoustic properties of the syllables [di] and [du] have no shared features which could explain the apparent perception of the same first segment in both (Liberman et al. 1967: 434–436; see also Port 2007: 151–152; 2010b: 48–49).

Furthermore, most acoustic speech cues are continuous in nature, e.g. voice-onset time, vowel formant values, and discrete categories cannot be reliably identified along the relevant continua (time, Hz, etc.).²

A wealth of additional evidence against the segmental approach to speech analysis is marshalled by

Port (e.g. 2006, 2007, 2010a,b). For example, dialectal variation and historical change very often involves gradual, even continuous, variation across articulatory and acoustic parameters, undermining the assumption that discrete segments can be associated with discrete articulatory or acoustic properties (Port 2010a: 307).³

A further issue concerns the assumptions specific to phonemic segmentation, for example the fact that distinct phonemes are not necessarily contrastive in all environments, meaning that it is not always possible to assign a particular segment to a specific phoneme (such as the second segment in words like *skill* and *spill*). Such issues are problematic for phoneme theory, but not for segmentation in general, since they could easily be surmounted by assuming that the second segment of onsets like /sk/ are identical neither with /k/ nor /g/, but represent a third segment type, or alternatively by assuming that onsets like /sk/ are actually single segments.⁴

If there are so many problems with segmental approaches to phonological analysis, why is it so popular and apparently intuitive? Firth (1948) was the first to claim that phonemic segmentation derives from alphabetic writing, and that we only perceive speech as naturally segmentable into phonemes because we have learnt an alphabetic writing system. More recently, Aronoff (1992: 79–80) argues that the segmental approach to speech analysis originates with de Saussure (1916), who even explicitly connected the concept with alphabetic writing:

The Greek alphabet was an ingenious discovery... A one-to-one ratio between sounds and graphs – the necessary and sufficient basis for a good phonological system of writing – was realized almost completely by the Greeks. Other nations did not grasp this principle, and their alphabets do not analyze the spoken chain according to its homogeneous auditory beats. The Cypriots, for example, stopped at more complex units like *pa*, *ti*, *do*, etc. (de Saussure 1916: 38–39)

De Saussure therefore treats the alphabet as a ‘discovery’ of the true basis of phonological analysis, i.e. linear segmentation. The assumption that phonemic linear segmentation is the true basis of phonological analysis is not otherwise justified by de Saussure. But if Western linguists are predisposed to perceive speech as linearly segmentable due to our alphabetic literacy and the centrality of written media to academic discourse, then the ongoing centrality of the phoneme in the development of modern Western phonology is brought sharply into question.

The claim that segmentation derives directly from alphabetic writing, and is therefore of doubtful scientific validity, is widely found, made e.g. by Robins (1967: 23), Lüdtke (1969: 173), Günther (1986: 258), Faber (1992: 112). More recently, Port (2006; 2007: 153–155; 2010a: 311–312)

explains the intuitive appeal and enduring success of segmentation in phonological analysis as directly due to alphabetic literacy:

It may be difficult for us to recall, but every person reading this page spent several hours a week for many years learning to read and to refine their reading skills. It is surely naïve to imagine that all this mental effort focused on use of an alphabet over several decades would have no consequences for our intuitions about the structure of language (Port 2010a: 311–312)

Psycholinguistic evidence in general supports this position. As discussed by Ziegler and Goswami (2005), experimental evidence shows clearly that awareness of segments derives almost entirely from alphabetic literacy, although certain types of linguistic structures found in some languages can support a certain degree of segmental awareness prior to literacy. In contrast, awareness of syllables, and even of onsets and rimes, precedes literacy.⁵

Taking a contrary perspective, Fowler et al. (2016: 126, 130) assume that the very existence of alphabetic writing, and the fact that most modern writing systems are alphabetic rather than syllabic or logographic, is evidence that phonetic segments are a real component of language competence. However, the fact that most written languages today use alphabets does not necessarily mean anything, since this has a primarily historical-cultural explanation. In fact the opposite argument can be made: the history of writing suggests the alphabet is a less natural means of representing speech than syllabic or logographic systems. Fundamental is the recognition that truly alphabetic writing was independently developed only once, in the development of Semitic-type consonantal writing and the subsequent adaptation of the Phoenician script to Ancient Greek, whereas logographic and syllable-based writing systems have been independently developed multiple times. The unique development of the alphabet, as against the relatively frequent independent development of logographic and syllabic writing systems, leads to claims that alphabetic segmentation of speech is less phonologically motivated than syllabic analysis.⁶

The alphabet was invented only once – because the alphabet is quite *unnatural* ... the syllable proves to be the most salient unit of the stream of speech. (Daniels 1992: 89)

In this context, non-Western traditions of linguistics are highly relevant, since if it can be shown that a tradition of linguistic analysis uninfluenced by alphabetic writing nevertheless treated speech as divisible into segment-sized units, the strength of the foregoing arguments would be

significantly reduced. As shown by Halliday (1981), Chinese phonological analysis did not extend to segment-sized units, drawing the line at subdividing syllables into onset and rime. The evidence from the ancient Mesopotamian tradition appears parallel (Daniels 1992: 92).

By far the most sophisticated non-Western linguistic tradition was that of ancient India. Firth (1948), followed by e.g. Lüdtke (1969: 165), stresses the less segmental, more syllabic nature of Indian writing systems (abugidas) as compared with alphabetic writing, and effectively takes Indian abugidas to be representative of the ancient Indian tradition of phonological analysis; Firth therefore concludes that this non-Western tradition had a much more appropriately syllabic, and less phonemic, approach to phonology precisely because it was not influenced by alphabetic writing.

While it is true that Indian abugidas are less phonemic, and more syllabic, than alphabetic writing, it must not be taken for granted that the ancient Indian tradition of phonological analysis is directly reflected in, or was even influenced by, this or any other kind of writing. In the following sections I show firstly, that the ancient Indian tradition was no less segmental, perhaps even phonemic, than our own, and secondly, that this fundamentally segmental tradition developed without the influence of segmental (or alphabetic) writing, indeed most likely without influence from any kind of writing whatsoever.

3 Phonetic/phonological analysis in the Indian tradition

The ancient Indian linguistic tradition is widely recognized to have been remarkably sophisticated for its time, in particular in relation to the tradition of grammatical analysis centered on the work of Pāṇini. Less widely known is the originally older tradition of phonetic and phonological analysis in ancient India. This tradition never attained the level of sophisticated analysis that Pāṇini achieved in morphosyntax, but it did attain a level of abstract analysis which can reasonably be called phonological, as well as a level of phonetic observation, particularly in regard to articulation, which was not surpassed in the West until the nineteenth century.⁷

3.1 Early texts

Linguistic thought in India developed in the context of understanding, analysing and preserving the early Vedic Sanskrit texts, which were central to the religious and ritual activity of the culture. The Vedic tradition, and the tradition of interpretation and analysis associated with it, was an entirely

oral tradition. To ensure accurate oral transmission and memorization, sophisticated recitation patterns were developed. The earliest known system is the *Padapāṭha* of the *Ṛgveda*: a word-by-word breakdown of the *Ṛgveda*, which in standard *saṃhitā* ‘continuous’ recitation only distinguished boundaries at the end of hemistichs and larger metrical units. The *Padapāṭha* may date to early in the first half of the first millennium BC, and shows clear evidence of linguistic analysis beyond the basics of word division.

The ultimate basis of segmental analysis in the Indian tradition is the inventory of sounds, the *akṣarasamāmnāya* or *varṇasamāmnāya*.⁸ Roughly, the inventory of sounds defines the set of vocalic and consonantal segments which are the object of phonetic analysis and the basis of phonological analysis. Importantly, the units correspond in size precisely to the segments of modern phonology: each segment corresponds to what would be one grapheme in an alphabetic transcription. The earliest references to this inventory appear in the *Aitareya Āraṇyaka* (3.2.1) and the *Chāndogya Upaniṣad* (2.22.3–5), which also name the major subgroupings of segments: vowel (*svara*), stops (*sparsā*), semi-vowels (*antasthā*) and fricative (*ūṣman*).⁹ In the earlier *Aitareya Brāhmaṇa* (5.32.2) we find the first explicit reference to the concept *varṇa* ‘sound segment’.

- (4) tebhyo... trayo varṇā ajāyanta=a-kāra u-kāro ma-kāra iti. tān
 them.ABL three sounds produced=‘a’ ‘u’ ‘m’ QUOT these.ACC
 ekadhā samabharat, tad etad om̐ iti.
 together/at_once brought_together that thus ‘om̐’ QUOT
 From these... three sounds were produced: ‘a’, ‘u’ and ‘m’. These he combined together/at
 once; in this way (he made the sacred syllable) ‘om̐’.

In this passage, the word *varṇa* is used to refer to three segment-like elements, *a*, *u* and *m*, which are treated as the constituent elements of the syllable *om̐*. Despite the focus here on the sacred syllable *om̐*, syllables are not the basic unit of analysis here: segments are treated as the fundamental building blocks of larger sound sequences, including syllables; syllables are not treated as independent of, or more fundamental than, the segments which constitute them.

According to Olivelle (1998: 12–13), the *Chāndogya Upaniṣad* dates to between 700–500 BC in its final form, and the *Aitareya Āraṇyaka* must be a similar age. The *Aitareya Brāhmaṇa* must be older than the *Aitareya Āraṇyaka*. Thus the sound inventory, and its groupings into types of sounds, must have been well developed before 500 BC at the absolute latest, and the tradition of segmentation which resulted in the sound inventory must be older. Most scholars would place these developments significantly earlier than 500 BC; Deshpande (1995: 73) dates the emergence of the ordered sound inventory to 700 BC.

3.2 The *Prātiśākhya*s

The earliest surviving specifically phonetic/phonological texts are the *Prātiśākhya*s.¹⁰ The extant *Prātiśākhya*s show influence from Pāṇini's *Aṣṭādhyāyī*, which cannot be later than 400–350 BC (Cardona 1976: 260–275), but in origin they are older, and preserve the tradition of phonological analysis attested in the earlier Vedic texts, i.e. the fundamentals of their approach must date to at least the sixth century BC.

The *Prātiśākhya*s describe the correct pronunciation of the earliest Vedic texts, based on the dual modes of recitation, *Samhitāpāṭha* and *Padapāṭha*. Essentially, the *Prātiśākhya*s assume a *Padapāṭha* text, with each word separated and pronounced in pausa, and provide rules for the combination of words into continuous sequences, the result being the running (*saṃhitā*) text. Thus the main concern of the *Prātiśākhya*s is accounting for sandhi phenomena between words. Other matters that might affect the proper pronunciation of the texts are also addressed.

3.2.1 Segmental analysis

The basic units of analysis in all the *Prātiśākhya*s are the same segment-like units already discussed as constituting the sound inventory in the Vedic period. All *Prātiśākhya*s presuppose a largely identical sound inventory, roughly as follows.¹¹

- (5) a ā ā3 i ī ī3 u ū ū3 ṛ ṝ ṝ̄ e o ai au
 k kh g gh ṇ c ch j jh ñ ṭ ṭh ḍ ḍh ṇ t th d dh n p ph b bh m
 y r l v ṣ ś s ṣ ḥ (ḥ) (ṁ)

Such a list is not directly transmitted in the *Prātiśākhya*s themselves (except in a probable later addition to the *Vājasaneyi-Prātiśākhya*), but can be easily reconstructed for each text; for example, the *Taittirīya-Prātiśākhya* begins with the following rules.

- (6)
- TP 1.1: *Atha varṇasamāmnāyaḥ* ‘Now the list of sounds:’
 - TP 1.2: *atha navāditaḥ samānākṣarāṇi* ‘now the first nine are the homogeneous syllables (=simple vowels);’
 - ...
 - TP 1.5: *ṣoḍaśāditaḥ svarāḥ* ‘the first sixteen are vowels;’
 - TP 1.6: *śeṣo vyañjanāni* ‘the rest are consonants;’

- TP 1.7: *ādyāḥ pañcaviṃśati sparśāḥ* ‘the first twenty-five (consonants) are the stops;’
- TP 1.8: *parāś catasro ’nthasthāḥ* ‘the next four are the semivowels;’
- TP 1.9: *pare ṣaḍ ūṣmānaḥ* ‘the next six are fricatives.’
- TP 1.10: *sparśānām ānupūrvyeṇa pañca pañca vargāḥ* ‘Among the stops, the successive fives are the series [i.e. voiceless unaspirated, voiceless aspirated, etc.]’

There are slight variations in the inventories assumed by the different *Prātiśākhya*s; the *Taittirīya-Prātiśākhya* does not include *ḥ* (‘visarga’, a voiceless glottal fricative) or *ṁ* (‘anusvāra’, a nasal element) as constituents of the sound list, while these are included in the sound list by other *Prātiśākhya*s. Crucially, only segmental elements are included. While *a* and *ā*, for example, are treated as sharing their ‘a-ness’ and differing purely in length, they are nonetheless treated as distinct segments, and crucially no nonsegmental features, such as length, are given any place in the inventory of basic units of analysis.

The most obvious candidate for a nonsegmental/suprasegmental element in the Sanskrit sound system is nasalization. The pure nasalization *ṁ* (‘*anunāsika*’) is never included in the sound list. The phonetic status of the anusvāra *ṁ* appears to have been variable (Cardona 2013): some texts analyse it as a kind of nasalization, others as a segmental nasal element; but only when it is treated as segmental is it included in the sound inventory (e.g. by the *Ṛk-Prātiśākhya*). The other major suprasegmental feature, accent (tone), likewise plays no role in the sound inventory. Such features are discussed, and their distribution and realization are carefully specified, but they play a distinctly secondary role in the analytical system of the *Prātiśākhya*s in comparison with the segmental units which constitute the sound inventory.

The secondary role of nonsegmental features is most apparent when we consider how phonological rules are framed in the *Prātiśākhya*s. The basic units of alternation and alteration are the linear segments. Rules standardly apply to single segments, and may convert them into other linear segments, or may delete or insert linear segments in particular positions. Nonsegmental features are treated as properties of individual segments (generally vowels). For example, consider sandhi of the following type:

$$(7) \quad tasmīn + tvā \rightarrow tasmīs tvā$$

That is, before a segment *t*, a final -*Vn* is realized with nasalization of the vowel and a sibilant segment. From a modern perspective, the nasalization of the vowel is due to the preservation of the

nasal feature of the *n*. A non-segmental (whether syllabic or feature-based) account could easily capture this fact. However, the treatment of this sandhi in the *Prātiśākhya*s works exclusively with segments: first the segment *n* is converted to a fricative segment *s* (TP 6.14), and then separately, a vowel segment is specified as nasalized if a following segment *n* has previously been converted to *s* (TP 15.1–3).

This does not mean that the authors of the *Prātiśākhya*s were unaware of the connection between the /n/ and the nasalization.¹² But the fundamentally secondary nature of nonsegmental sounds in the analytical system rendered this relation impossible to represent. Crucially, phonological rules in this system can convert segmental sounds into other segmental sounds, or they can delete or insert segmental sounds, or they can specify or alter a nonsegmental property of a segmental sound. But they cannot convert a segmental sound into a nonsegmental sound, or vice versa. The segment /n/ cannot be converted to nasalization, because nasalization is not a segment.

The different treatments of long vowels and long consonants is also telling. The phonetic discussions in the *Prātiśākhya*s imply that sequences of two like consonants were really long consonants. However, while there is an understanding that vowels of like quality can differ in length, there is no such understanding in the case of consonants. Sequences of two identical consonants are simply treated as such, precisely as in a modern transliteration. One consonant in Sanskrit cannot be long: *r*. This explains the sandhi *-Vr r- > -Ṽ r-*; from a modern perspective, the vowel lengthens because the consonant cannot have the feature LONG. The *Prātiśākhya* account, however, makes no attempt to capture this: it is explained (e.g. TP 8.6, 16–17) by deleting the first *r*, and then lengthening the vowel.

The treatment of what we might think of as ‘long aspirated’ consonants is also telling. These are sequences which are standardly transcribed as e.g. *ddh*, *bbh*, *tth*. In early inscriptions, these tend to be written simply *dh*, *bh*, etc. (just as e.g. *dd* is written simply *d*): the relevant property here is length, and early writing did not mark this. So *ddh* does not represent *d* followed by *dh*, but a long *dh*. But the *Prātiśākhya* tradition treats such sequences as e.g. *d+dh*, just as in the later writing tradition and in our transcription. So, the sandhi exemplified in:

(8) *yad hi > yaddhi*

can be explained very nicely with reference to features: *ddh*, understood as a long consonant, preserves the length, aspiration and point of articulation of the sequence *d+h*. But the tradition mechanically accounts for this by specifying the conversion of *h* into *dh* when preceded by *d* (and retention of *d* unchanged). These processes also illustrate the fact that no consonant cluster may

contain more than one aspiration; but this is not a feature of the *Prātiśākhya* analysis, because for them consonant clusters are just incidental sequences of the more basic units, segments.

Complex onsets are also treated as incidental sequences of segments, in line with modern segmentalism (see below ex. 2). *Svarabhakti* is a vowel segment (never part of the sound list), shorter than a full vowel, which is inserted between certain consonants, in particular between *r* and a following fricative. *Svarabhakti* thus appears to represent a slight gap in articulation between an *r* and a following fricative. However, this *svarabhakti* does not occur between an *r* and a following fricative-stop cluster.¹³ E.g. *-rs->-rṣ-*, but *-rst-* remains unchanged. This could be analysed on a non-segmental basis, assuming that fricative-stop clusters are not simply a sequence of fricative+stop.¹⁴ However, in the *Prātiśākhya*s the account is purely segmental: *svarabhakti* is inserted between *r* and a following fricative, but this insertion is cancelled if a stop follows the fricative.

While the *Prātiśākhya*s have a notion of nonsegmental sounds and features, then, these units play a secondary role in the analytical system: the fundamental unit of analysis is the segment.

3.2.2 Lack of syllabic analysis

It is also evident that the syllable plays no significant role in the analytical system of the *Prātiśākhya*s. They have such a notion, and discuss the syllabification of sequences of segments. But syllabification is secondary, and even referring to syllables in the rules is problematic. For example, in certain contexts, final *-aḥ* > *-o*. This can be accounted for using the standard mechanism (converting one linear segment into another), by converting the *ḥ* to *u*, and then relying on the fact that *a+u* > *o*. But one text, the TP (9.7), considers this a one-step change, that is *-aḥ* as a unit converts to *-o*. To do this the rule must be stated in an unwieldy way:

(9) *o-kāraṃ aḥ sarvo* ' *kāra-paraḥ* ' *aḥ* followed by *a*, all of it, becomes *o*.'

The addition of *sarvaḥ* 'all' is required because rules of conversion or deletion apply to single segments only, and the exception in this case has to be made clear. There is no neat way to refer to the syllable (or rime) *-aḥ* as a unit.

Consider also the treatment of *pumān-* 'male' > *pumś-* in compound before a palatal. This is a specific rule, applying only to this one lexeme when in compound, but is required in the *Atharva-Prātiśākhya*. Since the change must be specified purely by reference to phonological context, not lexical context (i.e. the noun *pumān-* itself cannot be referred to), the simplest phrasing

is that *-mān-* > *-mś-* in the relevant context following the syllable *pu-*. But the *Atharva-Prātiśākhya* states the preceding context as “when preceded by a *p* which is followed by a *u*”. The context of a specific syllable is referred to as a sequence of segments, because syllables play no part in the rules.

3.2.3 Segments or phonemes?

The evidence of the previous section demonstrates clearly that the *Prātiśākhya*s conform to the segmental principle given in 1 above. In this section I argue that it is reasonable to suppose they went further, to a level of abstract segmental analysis which can reasonably be called phonemic. The *Prātiśākhya*s evidently operate with a level of abstraction which we would call phonological. Beside detailed and insightful phonetic observations, there is a more abstract level of analysis which respects functional, and not phonetic, facts. Most obviously, the analysis assumes that the long vowel /a:/ is qualitatively identical to short /a/, which is valid on an abstract functional level, but not on a phonetic level; the texts recognize that in pronunciation /a/ is closer. In addition, not all segmentable units are treated as part of the functional system, but only those that function in alternation with other segments. This is seen with svarabhakti, discussed above, a segmentally distinct vowel element which never qualifies as a ‘segment’, because it is entirely conditioned by other sounds and plays no independent part in the alternations of the Sanskrit sound system. The most important criterion for phonemic, as opposed to simply segmental, analysis, was given in 2: phonemes represent equivalence classes of segments which stand in complementary distribution. Thus phonemes are a level of abstract analysis beyond segments; distinct segments may be grouped as allophones of a single phoneme. Deshpande (1995: 76) objects to the translation ‘phoneme’ for *varṇa* (hitherto ‘segment’), on the grounds that one or two distinct *varṇas* would not be classified as distinct phonemes in a modern phonemic analysis. For example, the tradition treats *ñ* as a distinct *varṇa*, whereas for a modern phonemic analysis it is an allophone of /n/ (Emeneau 1946). Deshpande (2000) argues that the basis of definition of the term *varṇa* is different from that of a phoneme in the Western tradition: a distinct *varṇa* may not correlate with a distinct phoneme, from the Western perspective, because the Indian tradition did not distinguish *varṇas* purely in terms of contrastive distribution but also, in a few cases, in terms of symmetry of the phonological system and in terms of relative phonetic values. However, modern (i.e. post-Chomskian) approaches to phonemes also move beyond mechanical reliance on contrastive distribution, depending also on articulatory similarity and a sensitivity to the psychological plausibility of a proposed phonemic system, in which symmetry may play a part.¹⁵ In this way, the

concept of *varṇa* may correlate with a more modern, less mechanical approach to the phoneme. Crucially, contrastive distribution plays a significant role in the definition of what does and does not qualify as a *varṇa*. For example, the term *abhinidhāna* is applied to stops in context before other stops, and in pausa; the descriptions of it clearly reflect an unreleased pronunciation (Allen 1953: 71–73). The term applies both to word-internal stops, and to word-final stops which appear in the relevant context only due to sandhi. The *abhinidhāna* pronunciation reflects a distinct segmental type, but *abhinidhāna* stops are not treated as distinct *varṇas* from their corresponding released stops. The *varṇa* *d*, for example, has (at least) two realizations, [d] and [dʰ], ‘allophones’ which stand in complementary distribution. Similarly, the *Ṛk-Prātiśākhya* treatment of the sequence stop+nasal recognizes the realization of the stop as distinct in this context: the stop has a nasal release (i.e. [dⁿ]).¹⁶

Evidence such as this suggests that the Sanskrit term *varṇa* does correlate with the notion of an abstract sound unit which subsumes multiple distinct sound segments (of sufficient phonetic similarity) standing in complementary distribution. The fact that the tradition gave the status of *varṇa* to some segments which, on a purely mechanical analysis, ought to be treated as allophones, does not mean that the underlying concept of *varṇa* was fundamentally different; it simply means that the tradition relied on more than simply contrastive distribution.¹⁷

The second principle of phonemic analysis, given in 3, is the relative equality of vowels and consonants. In the sound inventory all the vowels are listed before the consonants, showing that on some level they were perceived as distinct, but in terms of the rule system vowels and consonants are treated as having fundamentally the same linear segmental nature. There is no distinct treatment of vowels and consonants in the phonological rules of the *Prātiśākhya*s: single segments may be converted into other segments, and no differentiation is made between vocalic and consonantal segments. Vowels can be converted into consonants, and vice versa; no special attention is given to such cases. The obvious example is sandhi of word-final *i* and *u* (and *ī* and *ū*), which are converted to *y* and *v* respectively in context before a vowel.

I therefore take Sanskrit *varṇa* to be, in fundamentals, equivalent to the term *phoneme*; nevertheless, this is not crucial to the current argument: what matters is that the Indian tradition took the basic level of phonological analysis to involve absolute segmentation into phoneme-like, segment-sized, units. This is a significant fact, given the apparent lack of influence from alphabetic literacy in the development of the tradition.

4 Writing in ancient India

The fundamentally segmental nature of ancient Indian phonological analysis is problematic for attempts to attribute the primacy of segmentalism in modern Western phonology to alphabetic literacy. The important question now is: what writing, if any, might have influenced the development of the ancient Indian tradition?¹⁸

It is important firstly to emphasize that the Indian tradition within which linguistic analysis arose originated as an oral tradition long before the introduction of writing into India, and remained a specifically oral tradition for centuries after the introduction of writing into India; writing remained a marginal, and disapproved of, medium for transmission of Vedic texts (Allen 1953: 16). Thus even at the time when written versions of Vedic texts may have existed, the orally transmitted versions of those texts would have remained the primary versions in the minds of the linguists analysing them. And at the time when phonological analysis was developing, let us say 800–500 BC, even if there was writing in India, it was not yet used to write down Vedic texts (which may not have been written down until around the turn of the millenium). Moreover, the linguistic analyses themselves were developed and transmitted orally at this early period. This is very different from the Western tradition, where the written form of a text is treated as the default, where linguistic analysis almost exclusively takes place in written form, and where any oral transmission is closely accompanied by written media. So even if writing existed in India at the time when phonological analysis was developing, its effect on the consciousness of those undertaking phonological analysis of Vedic Sanskrit texts is likely to have been of a distinctly lesser order than the effect of writing on the consciousness of de Saussure and other early modern linguists to whom segmentalism in the West is attributed.

The question remains whether there is any evidence at all for writing in ancient India at the period when the segmental analysis attested in Vedic Prose and the *Prātiśākhya*s was developing.

Unfortunately, the date of the introduction of writing into India is highly controversial.¹⁹ There is no definitely agreed evidence for writing in India before the inscriptions of the Mauryan king Aśoka, c. 270–230 BC, but it seems highly likely that writing did exist in India before this. The earliest literary reference may be found in Pāṇini (no later than 400–350), but there is doubt as to whether the word in question, *lipi*, actually refers to writing.²⁰

There are three scripts relevant to the present question. Aramaic was introduced to north-west India following the Persian conquest of Gandhāra (c. 520 BC); it is unlikely that writing was known or used in any significant way in India before this. The oldest writing system indigenous to

India is Kharoṣṭhī, which originated in the north-west to write the local language Gāndhārī; it appears to be based on Aramaic, meaning that it cannot be earlier than the early fifth century. The main indigenous script, Brāhmī, is usually dated to the third century, e.g. by von Hinüber (1989), Falk (1993) and Salomon (1995: 278), but recent archaeological evidence may push its date back into the fourth or even fifth centuries (Coningham et al. 1996, Rajan and Yatheeskumar 2013, Premathilake et al. 2017).

Above, we saw that the Vedic texts which contain the earliest evidence for segmental analysis and the development of the segmental sound inventory are likely to date between 700 and 500 BC. Given the very latest part of this range, influence from Aramaic is just barely conceivable, but we have no evidence how quickly Aramaic spread from the far north-west to central India, and it seems more than likely that the texts in question were composed either before the introduction of Aramaic to Gandhāra, or before the spread of Aramaic (or Aramaic-influenced Kharoṣṭhī or Brāhmī) across north India. Even if such scripts were in use, they were initially used only for vernacular languages, not Sanskrit, and the likelihood of significant influence on the oral Sanskrit academic tradition seems exceptionally small.

However, let us push the argument, and assume that Aramaic was somehow known in India before 520 BC, or that the crucial Vedic texts have somehow been dated too early. And let us further assume that, however unlikely, the Vedic scholars whose tradition remained exclusively oral, and opposed to the influence of writing for centuries, were nevertheless influenced in their orally based phonological analysis of oral Sanskrit texts by (a) writing system(s) used for trade/administration purposes in languages other than Sanskrit. Even then, the segmental analysis found in the Indian tradition does not show the sort of influence we might expect had it been influenced by Aramaic, Kharoṣṭhī or Brāhmī.

Aramaic, Kharoṣṭhī and Brāhmī are not alphabetic scripts in the same way as the Ancient Greek and Roman scripts, with signs for vowel and consonant segments treated equally and linearly arranged. Aramaic was a consonantal script, with linearly arranged signs for consonantal segments, but no specialized signs for vowels. Kharoṣṭhī and Brāhmī, like later Indian scripts, are abugidas: they have signs for consonants which, without modification, are read as syllables with consonantal onset and /a/ vowel rime, but which can be modified with diacritics to indicate rimes with different vowels. Had knowledge of any of these scripts influenced Indian phonological analysis, we might expect vowels and consonants to be treated differentially, and/or the vowel /a/ to be given special status as a ‘default’ vowel; that vowels and consonants are treated as fundamentally of the same order, and that /a/ is not given any special treatment, cannot be attributed to the influence of writing.

Early Kharoṣṭhī and Brāhmī, moreover, failed to make many phonologically crucial distinctions which are made in the *Prātiśākhya*s.²¹ Vowel length was usually unmarked, and geminate consonants were not distinguished from nongeminates. Yet the distinction between long and short vowels and consonants is made perfectly in the Indian tradition from the earliest attested stage. Several sounds specific to Sanskrit (*ṛ*, *au*, *ṇ* and *ḥ*) have no means of representation in Kharoṣṭhī and Brāhmī before the turn of the millennium, and other features specifically required for writing Sanskrit are not developed until this period, including the *halanta* or *virāma*, the means of marking a final consonant in pausa (Salomon 1998: 37). But these sounds are given no special treatment in the linguistic tradition, nor treated as in any way questionable or exceptional.

Indication of consonant clusters was “rudimentary or even totally absent” in the immediate prototypes of the earliest attested forms of Kharoṣṭhī and Brāhmī (Salomon 1998: 14), partly because the Prakrits for which these scripts were developed had relatively few consonant clusters. Yet the Indian tradition shows no confusion over the analysis of consonant clusters specific to Sanskrit. Furthermore, in early Kharoṣṭhī in particular, many apparent conjunct consonant signs are not readily segmentable, e.g. the sign for /st/ is not readily derivable from the signs for /s/ and /t/, as is standard in later scripts, which suggests a less segmental and more syllabic writing system, with onset clusters unsegmented. But the Indian tradition shows no sign of this whatsoever: onset clusters are without exception fully segmented.²²

Thus even granted the chronologically unlikely scenario that writing could have influenced the development of the Indian phonological tradition, the Indian tradition shows no signs of such influence, and even appears to have gone well beyond the possible influence of writing in the direction of a segmental analysis of language. The segmental tradition attested in the *Prātiśākhya*s is more segmental than we would expect had it been influenced by writing.

5 Conclusion

It seems overwhelmingly likely, therefore, that the early Indian phonological tradition developed without influence from any alphabetic or segmental writing system. Yet, as we have seen, from its very earliest stages this tradition is fundamentally segmental in its approach, assuming abstract segment-sized units as the basic units of phonological analysis. This fact renders unsustainable the claim that a fundamentally segmental approach to phonological decomposition developed only once, due to the unique creation of alphabetic writing by the Greeks.

It is worth considering why and how the ancient Indian tradition developed its fundamentally segmental approach, as opposed to, say, a syllable-based approach as is found in the ancient Chinese tradition. It may be significant that the Indian tradition did not set about phonological analysis without bias: it had a specific goal, to preserve the Vedic texts unchanged in oral transmission, and in particular to preserve the relation between the *saṃhitā* and *pada* recitations by comprehensively accounting for sandhi phenomena. Thus sandhi between words constituted the primary data on the basis of which early phonological analysis developed; and it so happens that sandhi in Sanskrit almost exclusively targets the final and initial segments of words. The phenomena they sought to account for therefore biased the early Indian phonologists towards a segmental analysis of speech.

The Indian segmental approach did not therefore develop in the absence of specific biasing factors, but crucially, unlike in the West, the basis of the segmental approach was thoroughly linguistic, dependent on linguistic data rather than a historically contingent writing system. As discussed above, Ziegler and Goswami (2005) show that phoneme awareness almost entirely derives from alphabetic literacy, but they also show that certain linguistic structures support some degree of phoneme awareness in the absence of literacy. It appears, then, that the phonological structure of Sanskrit, and in particular the importance of initial and final segments for sandhi processes, facilitated segmental awareness among the early Indian phonologists, to such an extent that it led to the development of a fundamentally segmental approach to the Sanskrit sound system, with the more perceptible units of syllable, onset and rime playing no significant role in their approach. This development is entirely without parallel among the world's linguistic traditions.

It is, finally, worth noting the possibility that the ancient Indian and modern Western emphases on segments may not be entirely independent. Rather than taking the Indian tradition to provide a contrast to the segmental bias of the West, as Firth (1948) did, it may be rather that the segmental approach of the Indian tradition further strengthened the bias toward a segmental approach in the West. As discussed by Allen (1953: 3–4), the influence of ancient Indian phonetic analysis runs deep in the development of modern phonetics. According to Firth (1946), 'Without the Indian grammarians and phoneticians whom [Sir William Jones] introduced and recommended to us, it is difficult to imagine our [i.e. the English] school of phonetics.' In this light, then, it may in fact remain the case that a fundamentally segmental approach to phonological analysis developed entirely independently only once – yet it was not in the West, under the influence of alphabetic writing, that this developed, but in preliterate ancient India.

References

- ALLEN, W. SIDNEY (1953). *Phonetics in Ancient India*. London: Oxford University Press.
- ARONOFF, MARK (1992). 'Segmentalism in linguistics: The alphabetic basis of phonological theory'. In Pamela Downing, Susan D. Lima, and Michael Noonan (eds.), *The linguistics of literacy*, Amsterdam: Benjamins, pp. 71–82.
- CARDONA, GEORGE (1976). *Pāṇini: A survey of research*. The Hague: Mouton.
- CARDONA, GEORGE (2013). 'Developments of nasals in early Indo-Aryan: anunāsika and anusvāra'. *Tokyo University Linguistic Papers* 33, pp. 3–81.
- CONINGHAM, R.A.E., F.R. ALLCHIN, C.M. BATT, and D. LUCY (1996). 'Passage to India? Anuradhapura and the early use of the Brahmi script'. *Cambridge Archaeological Journal* 6(1), pp. 73–97.
- DANIELS, PETER T. (1992). 'The syllabic origin of writing and the segmental origin of the alphabet'. In Pamela Downing, Susan D. Lima, and Michael Noonan (eds.), *The linguistics of literacy*, Amsterdam: Benjamins, pp. 83–110.
- DE SAUSSURE, FERDINAND (1916). *Cours de linguistique générale*. Paris: Payot. Published by Charles Bally and Albert Sechehaye, with the assistance of Albert Riedlinger. Translation by Wade Baskin, published by Peter Owen, London, 1960.
- DESHPANDE, MADHAV M. (1995). 'Ancient Indian phonetics'. In R. E. Asher and E. F. K. Koerner (eds.), *Concise history of the language sciences: From the Sumerians to the cognitivists*, Oxford: Pergamon, pp. 72–77.
- DESHPANDE, MADHAV M. (1997). *Śaunakīyā Caturādhyāyikā: a Prātiśākhya of the Saunakīya Atharvaveda, with commentaries Caturādhyāyībhāṣya, Bhārgava-Bhāskara-Vṛtti and Pañcasandhi*. Cambridge, MA: Department of Sanskrit and Indian Studies, Harvard University.
- DESHPANDE, MADHAV M. (2000). 'Indian theories on phonetics'. In Sylvain Auroux, E. F. K. Koerner, Hans-Josef Niederehe, and Kees Versteegh (eds.), *History of the language sciences: An international handbook on the evolution of the study of language from the beginnings to the present* (Vol. 1), Berlin: de Gruyter, pp. 137–146.

- EMENEAU, M. B. (1946). 'The nasal phonemes of Sanskrit'. *Language* 22(2), pp. 86–93.
- FABER, ALICE (1992). 'Phonemic segmentation as epiphenomenon: evidence from the history of alphabetic writing'. In Pamela Downing, Susan D. Lima, and Michael Noonan (eds.), *The linguistics of literacy*, Amsterdam: Benjamins, pp. 111–134.
- FALK, HARRY (1993). *Schrift im alten Indien: Ein Forschungsbericht mit Anmerkungen*. Tübingen: Narr.
- FALK, HARRY (2018). 'The creation and spread of scripts in ancient India'. In Anne Kolb (ed.), *Literacy in ancient everyday life*, Berlin: de Gruyter, pp. 43–66.
- FARMER, STEVE, RICHARD SPROAT, and MICHAEL WITZEL (2004). 'The collapse of the Indus-script thesis: the myth of a literate Harappan civilization'. *Electronic Journal of Vedic Studies* 11(2), pp. 19–57.
- FIRTH, J. R. (1936). 'Alphabets and phonology in India and Burma'. *Bulletin of the School of Oriental and African Studies* 8(2–3), pp. 517–546.
- FIRTH, J. R. (1946). 'The English school of phonetics'. *Transactions of the Philological Society* 45(1), pp. 92–132.
- FIRTH, J. R. (1948). 'Sounds and Prosodies'. *Transactions of the Philological Society* 47(1), pp. 127–152.
- FOWLER, CAROL A., DONALD SHANKWEILER, and MICHAEL STUDDERT-KENNEDY (2016). 'Perception of the speech code revisited: Speech is alphabetic after all'. *Psychological Review* 123(2), pp. 125–150.
- GALANTUCCI, BRUNO, CAROL A. FOWLER, and M. T. TURVEY (2006). 'The motor theory of speech perception reviewed'. *Psychonomic Bulletin & Review* 13(3), pp. 361–377.
- GÜNTHER, HARTMUT (1986). 'Was the alphabet discovered or invented? On the alleged common processes in speech and writing'. In Gerhard Augst (ed.), *New trends in graphemics and orthography*, Berlin: de Gruyter, pp. 248–261.
- HALLIDAY, MICHAEL A. K. (1981). 'The origin and early development of Chinese phonological theory'. In R. E. Asher and E. J. A. Henderson (eds.), *Towards a history of phonetics*, Edinburgh: Edinburgh University Press, pp. 123–140.

- JONES, DANIEL (1950). *The phoneme: its nature and uses*. Cambridge: W. Heffer & Sons Ltd.
- LIBERMAN, ALVIN M., FRANKLIN S. COOPER, DONALD P. SHANKWEILER, and MICHAEL STUDDERT-KENNEDY (1967). 'Perception of the speech code'. *Psychological Review* 74, pp. 431–461.
- LÜDTKE, H. (1969). 'Die Alphabetschrift und das Problem der Lautsegmentierung'. *Phonetica* 20, pp. 147–176.
- MAHULKAR, D. D. (1981). *The Prātiśākhya tradition and modern linguistics*. Baroda: Department of Linguistics, M.S. University of Baroda.
- MASSARO, DOMINIC W. (1972). 'Preperceptual images, processing time, and perceptual units in auditory perception'. *Psychological Review* 79, pp. 124–145.
- MASSARO, DOMINIC W. and TREVOR H. CHEN (2008). 'The motor theory of speech perception revisited'. *Psychonomic Bulletin & Review* 15(2), pp. 453–457.
- MASSARO, DOMINIC W. and GREGG C. ODEN (1980). 'Speech perception: A framework for research and theory'. In N. J. Lass (ed.), *Speech and language: Advances in basic research and practice* (vol. 3), New York: Academic Press, pp. 129–165.
- MÜLLER, MAX (1869). *Rig-Veda-Pratisakhya: das älteste Lehrbuch der vedischen Phonetik. Sanskrittext mit Übersetzung und Anmerkungen*. Leipzig: F.A. Brockhaus.
- NIETO-CASTANON, ALFONSO, FRANK H. GUENTHER, JOSEPH S. PERKELL, and HUGH D. CURTIN (2005). 'A modeling investigation of articulatory variability and acoustic stability during American English /r/ production'. *The Journal of the Acoustical Society of America* 117, pp. 3196–3212.
- ODEN, GREGG C. and DOMINIC W. MASSARO (1978). 'Integration of featural information in speech perception'. *Psychological Review* 85, pp. 172–191.
- OLIVELLE, PATRICK (1998). *The Early Upaniṣads: annotated text and translation*. Oxford: Oxford University Press.
- PORT, ROBERT F. (2006). 'The graphical basis of phones and phonemes'. In Murray J. Munro and Ocke-Schwen Bohn (eds.), *Second language speech learning: The role of language experience in speech production and perception*, Amsterdam: Benjamins, pp. 349–365.

- PORT, ROBERT F. (2007). 'How are words stored in memory? Beyond phones and phonemes'. *New Ideas in Psychology* 25, pp. 143–170.
- PORT, ROBERT F. (2010a). 'Language as a social institution: Why phonemes and words do not live in the brain'. *Ecological Psychology* 22(4), pp. 304–326.
- PORT, ROBERT F. (2010b). 'Rich memory and distributed phonology'. *Language Sciences* 32, pp. 43–55.
- PORT, ROBERT F. and ADAM P. LEARY (2005). 'Against formal phonology'. *Language* 81(4), pp. 927–964.
- PREMATHILAKE, R., K. ANUPAMA, K. RAJAN, S. PRASAD, G. ORUKAIMANI, and V. P. YATHEES KUMAR (2017). 'Implications of phytolith records from an Early Historic megalithic burial site at Porunthal in Southern India'. *Journal of Archaeological Science: Reports* 11, pp. 491–506.
- RAJAN, K. and V. P. YATHEESKUMAR (2013). 'New evidences on scientific dates for Brāhmī script as revealed from Porunthal and Kodumanal excavations'. *Prāgdhārā* 21–22, pp. 280–295.
- RENOU, LOUIS and JEAN FILLIOZAT (1953). *L'Inde fondamentale: Etudes d'indianisme réunies et présentées par Charles Malamoud*. Paris: Imprimerie Nationale.
- ROBINS, R. H. (1967). *A short history of linguistics*. London: Longmans.
- SALOMON, RICHARD (1990). 'New evidence for a Gāndhārī origin of the arapacana syllabary'. *Journal of the American Oriental Society* 110(2), pp. 255–273.
- SALOMON, RICHARD (1995). 'On the origin of the early Indian scripts'. *Journal of the American Oriental Society* 115(2), pp. 271–279.
- SALOMON, RICHARD (1998). *Indian epigraphy: A guide to the study of inscriptions in Sanskrit, Prakrit, and the other Indo-Aryan languages*. Oxford: Oxford University Press.
- SCHARF, PETER M. (2013). 'Linguistics in India'. In Keith Allan (ed.), *The Oxford Handbook of the History of Linguistics*, Oxford: Oxford University Press, pp. 227–257.
- SCHARF, PETER M. and MALCOLM D. HYMAN (2011). *Linguistic issues in encoding Sanskrit*. Providence: The Sanskrit Library.

- SHARMA, V. VENKATARAMA (1930). *Taittirīya Prātiśākhya with Māhiṣeya's Bhāṣya*. Madras: University of Madras.
- SHARMA, V. VENKATARAMA (1934). *Vājasaneyi Prātiśākhya of Kātyāyana with the commentaries of Uvaṭa and Anantabhaṭṭa*. Madras: University of Madras.
- SHASTRI, MANGAL DEVA (1931). *The Rgveda-Pratisakhya with the commentary of Uvaṭa. Volume II*. Allahabad: Indian Press Ltd.
- SHASTRI, MANGAL DEVA (1937). *The Rgveda-Pratisakhya with the commentary of Uvaṭa. Volume III*. Lahore: Motilal Banarsidas.
- SHASTRI, MANGAL DEVA (1959). *The Rgveda-Pratisakhya with the commentary of Uvaṭa. Volume I*. Varanasi: V.S. Mandira.
- SHASTRI, SURYA KANTA (1933). *Ṛktantram: a prātiśākhya of the Sāmaveda*. Lahore: Mehar Chand Lachhman Das.
- SHASTRI, SURYA KANTA (1939). *Atharva Prātiśākhya*. Lahore: Mehar Chand Lachhman Das.
- TWADDELL, W. FREEMAN (1935). *On defining the phoneme*. Baltimore: Linguistic Society of America. *Language Monograph* 16.
- VAN NOOTEN, BAREND A. (1973). 'The structure of a Sanskrit phonetic treatise'. *Acta et commentationes Universitatis Tartuensis: Oriental Studies II*(2), pp. 408–436.
- VON HINÜBER, OSKAR (1989). *Der Beginn der Schrift und frühe Schriftlichkeit in Indien*. Mainz: Akademie der Wissenschaften und der Literatur.
- WHITNEY, WILLIAM DWIGHT (1862). *The Atharva-veda Prātiṣākhya, or, Çāunakîyâ caturādhyâyikâ: text, translation and notes*. New Haven: American Oriental Society.
- WHITNEY, WILLIAM DWIGHT (1871). *The Taittirīya-Prātiṣākhya: with its commentary, the Tribhāshyaratna*. New Haven: American Oriental Society.
- ZIEGLER, JOHANNES C. and USHA GOSWAMI (2005). 'Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory'. *Psychological Bulletin* 131(1), pp. 3–29.

Notes

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¹For detailed discussions of the concept ‘phoneme’ see e.g. Twaddell (1935) and Jones (1950).

²My thanks to Robert Port on these points. In contrast, Fowler et al. (2016) claim that there are perceptible acoustic signatures in the speech stream associated with discrete segments. Their argument rests partly on the motor theory of speech perception: perceiving speech is perceiving gestures. Galantucci et al. (2006) provide a variety of evidence in support of the motor theory of speech perception; Nieto-Castanon et al. (2005) and Massaro and Chen (2008) argue rather that there is not necessarily any greater degree of consistency between articulatory gestures corresponding to the ‘same’ segment than there is between the corresponding acoustic signals.

³Port (2010a) argues not simply against the segmental analysis of speech, but against all formalist approaches to phonology in general, i.e. against all approaches which treat human phonological competence in terms of a formal symbolic system. See especially Port and Leary (2005).

⁴Relevant here is the question whether segmentation into units larger than the standard letter sized ‘segments’ might avoid many of these problems. For example, Massaro (1972), Oden and Massaro (1978) and Massaro and Oden (1980) argue that syllable sized units are perceptually less variant than segments, and thus are a better basis for speech perception. In general, however, arguments concerning segmentation take standard letter-sized segments to be the basic assumption (as e.g. Port 2010a).

⁵See also Port (2007: 152–153) with further references.

⁶A similar comment is made by Lüdtkke (1969: 155).

⁷For an overview of linguistic analysis in India, see Scharf (2013).

⁸Following Deshpande (2000), the use of *akṣara* in *akṣarasamāmnāya* is an extension of the term *akṣara* ‘syllable’ to the sense ‘segment’; it does not imply an earlier period (for which we would have no other evidence) in which syllables were the primary units of analysis (contra Mahulkar 1981).

⁹The category of semi-vowel is noted as a recent proposal in the *Aitareya Āraṇyaka*, and does not appear in the *Chāndogya Upaniṣad*.

¹⁰For an overview and introduction to the Indian phonetic and phonological literature, see Allen 1953, and on the Sanskrit sound system also Scharf and Hyman 2011: 61–78. Editions and translations of *Prātiśākhya* texts include those by Müller (1869), Whitney (1862, 1871), Shastri (1933, 1939), Sharma (1930, 1934), Shastri (1931, 1937, 1959), Deshpande (1997).

¹¹The list is given in standard transliteration. The exact articulation of each sound is treated in the *Śikṣā* literature, with reference to organ and place of articulation, degree of stricture, and the binary features of voicing and aspiration; see e.g. van Nooten (1973). IPA equivalents would be roughly the following: a, a:, i, i:, u, u:, ɾ, ɽ, ɱ, e, o, ai, au, k, k^h, g, g^{fi}, ŋ, c, c^h, ʃ, ʃ^{fi}, ʒ, ʒ^h, ɖ, ɖ^{fi}, ɳ, t, t^h, d, d^{fi}, n, p, p^h, b, b^{fi}, m, j, ɭ, l, v, x, ʃ, ʂ, s, ʂ, ɸ, ɦ. The phonetic status of *m* is variable, as discussed below.

¹²Both the *Prātiśākhya* and *Śikṣā* literature recognize that nasal consonants have the same property of nasality, *ānunāsikyam*, as nasalization itself (and anusvāra), and define this as involving the passage of air through the nasal

cavity. Overall, the Indian tradition had a relatively sophisticated understanding of the shared phonological properties of the different speech sounds, which approximates the Western decomposition of segments into bundles of features. Cf. fn. 11 above.

¹³Under some analyses svarabhakti is more widespread; it does occur between an *r* and a following fricative-stop cluster but is longer between an *r* and a following fricative which is not part of such a cluster.

¹⁴Cf. the discussion of Firth below 1 above, and the discussion of early Kharoṣṭhī below.

¹⁵Hence why, for example, English /ɪ/ and /h/ are not generally considered allophones, despite the fact that, as earlier critics of phoneme theory liked to point out, they stand in complementary distribution in English and on a purely mechanical approach should be subsumed under a single phoneme.

¹⁶Allen (1953: 75–78).

¹⁷Or, perhaps, that the tradition erred in its analysis of particular cases.

¹⁸In general on the introduction of writing into India, see von Hinüber 1989, Falk 1993, 2018, and most importantly Salomon 1995 and Salomon 1998.

¹⁹I ignore here the so-called ‘Indus Valley script’, which may well not represent writing (Farmer et al. 2004). Even if the Indus Valley civilization was literate, there is no evidence that this literacy survived the collapse of the civilization; the later development of literacy was entirely unrelated.

²⁰Compare von Hinüber 1989: 57–58 and Falk 1993: 258–259. Beside Pāṇini’s reference to *lipi*, the earliest references may be in the Pāli *Tipiṭaka*, but von Hinüber (1989) and Falk (1993) similarly argue that these reference may be either late additions, or may not actually refer to writing.

²¹See in particular Salomon 1998.

²²On Kharoṣṭhī conjuncts see Salomon 1990: 268–270. Further arguments against the influence of Semitic writing in particular are given by Renou and Filliozat (1953: 668).