Alphabetics

From phonemes to letters or from letters to phonemes?

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This paper is concerned with the relation between our capacity for alphabetic reading and writing the sound forms of languages on the one hand, and the structure of speech and language on the other. It starts from two questions: (1) What structural properties of human languages enable us to read and write their sound forms with a handful of alphabetic symbols? (2) Why is learning this skill so difficult? Ad (1) it is argued here that the basis for reading and writing in an alphabet is the inherent segmentability of speech, stemming from the synchronization of articulatory gestures during speech production. This synchronization arises from inherent properties of both speech production and speech perception. Ad (2) it is suggested here that learning to read and write with alphabetic letters is so difficult, because in the mental structure of sound forms there are no pre-existing discrete phoneme-sized segments, at least not of a kind that language users are easily aware of. This makes analysis of sound forms into such phoneme-sized segments difficult, although such analysis is a prerequisite skill for alphabetic reading and writing. For easy learning, the relation between letters and speech segments should preferably be systematic and transparent.

1. Some questions

Alphabetic writing is the most successful writing system ever. It can be applied to every human natural language and it has been applied to many more languages than any other writing system. In most known countries of the world, alphabetic reading and writing plays an important role in society. In a great many of our societies the use of an alphabet for reading and writing is so pervasive that superficially it seems to come naturally to all of us, in the same manner listening and speaking do. Of course we all know that that is an illusion. World-wide there are hardly any adults who find listening and speaking in their native language difficult

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in the same way that most adult people in the world have difficulty in reading and writing. Virtually all healthy adults listen and speak with no apparent difficulty, in all countries in the world. But for example in Burkina Faso c. 80% of the population older than 15 years is completely illiterate. According to a website of the United Nations, world-wide currently c. 20% of all adults is completely illiterate. It is stated in a webpage of the Dutch "Stichting Lezen en Schrijven" ("Foundation for Reading and Writing") that in the Netherlands, although literacy according to the criteria of the United Nations is virtually 100%, 6 percent of all employed people, 1 in 15 workers, have such great difficulty with reading and writing that they are socially hampered by it.

Another obvious indication that reading and writing do not come naturally to individuals is that those who successfully learn to read and write, in virtually all cases have to be taught explicitly by a teacher, generally in a class room, and at a much later age than that they learn speech. In western European countries children generally get their first lessons in reading and writing somewhere between 5 and 7 years of age, when they have been fluent speakers for years.

Also, if the use of an alphabet would come naturally to people, one would have expected that in history, alphabetic reading and writing would have been arisen many times over. This is definitely not the case. As far as we know, the development of the alphabetic principle, allowing one symbol for each vowel and each consonant, occurred only once. That development took place roughly 5000–3000 years ago among the peoples living at the east end of the Mediterranean. The development found its culmination when some 750 years B.C. the Greek adapted the Phoenician script to their own language, giving a separate symbol to each of the consonants and each of the vowels in their language (Cf. Figure 1; Gelb 1952, Robinson 1995).

Apparently, although the alphabet provides us with a most successful and comparatively easy-to-learn writing system, acquiring the skill to use an alphabetic

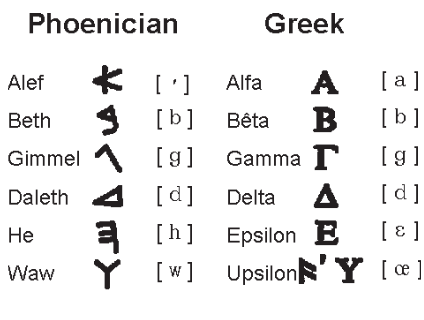

Figure 1. Some examples of characters taken from the Phoenician forerunner of the alphabet and from the early Greek alphabet. The first fully alphabetic writing system arose when the Greek started to write their own language with the symbols used by the Phoenicians.

script is difficult for all of us and prohibitively difficult for many of us. These considerations leave us with the following two questions:

1. What is it in the structure of human languages that enables us to read and write their sound forms with a handful of alphabetic symbols?
2. Why is learning to read and write so difficult?

Possible answers to these questions, as suggested by opinions in the literature about the structure of speech and language, have differed widely through the centuries. As we will see later, they still differ widely today. Recent results from research on the nature of the building blocks of speech during speech encoding suggest answers that for some will confirm what they always thought and for others may come as a surprise.

2. Some opinions on speech and language through the ages

Just a few hundred years after the alphabet had fully developed in Greece, in the 4th century B.C., Aristotle wrote:

> *"Just as all men have not the same writing, so all men have not the same speech sounds, but the mental experiences, which these directly symbolize, are the same for all (…)"* (Aristotle 350 B.C., translation by E.M. Edghill).

If we interpret here "mental experiences" as corresponding to "speech sounds", this is a remarkably modern insight, foreshadowing, as we will see in a moment, the notion of the "phoneme" as a psychological unit, contrasting with the highly variable nature of speech. It took more than 2200 years before this insight re-emerged in the writings of Jan Baudouin de Courtenay in 1895.

In between Aristotle and Baudouin de Courtenay, those who thought about the nature of speech were more concerned with the question whether speech sounds can be further analyzed in constituting parts. Petrus Montanus, a Dutch vicar who in his church taught children to read and write, proposed in his book "the Spreeckkonst" (or "The Art of Speaking" 1635) a tripartition of each speech sound in a "body", a "pre-attachment", and a "post-attachment". In different terms we find a similar tripartition of speech sounds in Sievers (1881), Rousselot (1897), Jespersen (1920), Zwaardemaker and Eykman (1928), Jones (1918). Apparently, Aristotle's insight that discrete speech sounds on the one hand and the continuous and variable nature of speech on the other hand are phenomena on different levels of description had been lost. This insight re-emerged in the writings of Jan Baudouin the Courtenay (1895) who coined the term "phoneme", defined by him as follows:

> *"(A phoneme) is generated in the mind by a psychological fusion of impressions made by different pronunciations of the same sound = a psychological equivalent of the speech sound"* (translation from German by Fischer-Jørgensen, 1975).

Reactions to this proposal have varied widely, leaving us with at least the following stand-points:

1. The phoneme is an abstract mental unit (Baudouin de Courtenay 1895)
2. The phoneme is a physical unit (Bloomfield 1933, Jones 1918)
3. The phoneme is a perceptual unit (Zwirner & Zwirner 1936, Jakobson & Halle 1956)
4. The phoneme does not exist at all (Menzerath & de Lacerda 1933, Scripture 1927), but is a useful fiction (Twaddell 1935, Truby 1959).

That today so many linguists and psycholinguists believe in the psychological reality of discrete, unanalyzable, abstract phonemes, might be because we all are "irrefragably conditioned" by the letters of the common alphabet (Truby 1959: 124–125) . Perhaps it is time to look for some more empirical evidence, one way or the other.

3. Are the planning units in speech production abstract unanalyzable phonemes?

There are several forms of empirical evidence relating to the hypothesized role of discrete, abstract phonemes as planning units in speech production. An often cited form of evidence is provided by segmental errors of speech, such as "moggy barsh" for "boggy marsh", "mell wade" for "well made", "Yew Nork" for "New York", "hinch hit" for "pinch hit", "corkical for "cortical" (all taken from Fromkin, 1973), where apparently the sounds of speech move around as a compositor's letters. The study of speech errors as a window on the mental processes in speech production originated with Meringer (1908, Meringer & Mayer 1895). Levelt (1989) repeatedly calls on segmental or phonological speech errors as evidence for abstract, discrete phonemes as planning units in speech production. A strong formulation is used by Levelt, Roelofs and Meyer (1999), who stated:

> *"Stored word forms are decomposed in abstract phoneme-sized units. This assumption is based on the finding that segments are the most common error units in sound errors; 60–90% of all sound errors are single-segment errors".*

We should be aware, however, that studies of phonological speech errors, either in spontaneous speech or elicited in the laboratory, virtually always heavily rely on transcription with alphabetic symbols, either the letters of the common orthography or letters from the phonetic alphabet. Collectors of errors of speech may have been misled by their "irrefragable conditioning" to the letters of the alphabet.

Evidence of a quite different nature is provided by a technique applied by Wheeldon and Levelt (1995), who had subjects monitor their own inner speech, where the inner speech consisted of a translation of words from another language into their own language. Monitoring latencies were a function of the position of the segment in the word, and a concurrent articulation task had little effect on performance. The main conclusion of their experiments was that their subjects were monitoring a phonemic, not a phonetic representation of the words in question. This would suggest that inner speech consists of a phonemic, not a phonetic representation.

Yet another form of evidence is exemplified in chronometric experiments by Roelofs (1999), who demonstrated that word production is facilitated when response words are produced in blocks of trials where these response words shared the initial phoneme, but not when the response words had either entirely different initial phonemes or initial phonemes that differed only in voicing. Facilitation was also found when the words shared the initial syllable, but not when these initial syllables differed in a single phonological feature in the onset. This suggests that on the level where facilitation occurs phonemic identity matters, and low level phonetic similarity does not.

However, the most convincing evidence in favour of phonemes as planning units in speech production still seems to come from segmental errors of speech. If indeed abstract, discrete, unanalyzable phonemes are planning units of speech production, we can make the following predictions for segmental errors of speech:

1. In speech errors sound segments move around like the letters of a compositor.
2. Speech errors involving features instead of whole phonemes are extremely rare.
3. Speech errors obey the phonotactic rules of the language: In English "blin" is a possible error, but "bnin" is not.
4. Speech errors do not create blends of different phonemes.

These predictions seemingly agree with observations made by many students of speech errors (see for example Wells 1951, Cohen 1966, Nooteboom 1969, Fromkin 1971, Shattuck-Hufnagel 1979, Dell 1986, Levelt 1989). We have seen already, however, that most collections of speech errors are made by noting down speech errors in some form of transcription. Possibly, transcription in alphabetic-phonetic symbols introduces artifacts that may distort our picture of the structure of speech.

4. Evidence from elicited errors of speech

Some time ago (cf. Nooteboom 2005) I did a laboratory experiment eliciting spoonerisms (consonant reversals as in "bad game" turning into "gad bame"). Elicitation was done with the so-called SLIP (Spoonerisms of Laboratory-Induced Predisposition) technique (Baars, Motley & MacKay 1975).

This technique works as follows: Participants are successively presented visually, for example on a computer screen, with word pairs such as DOVE BALL, DEER BACK, DARK BONE, BARN DOOR, to be read silently. On a prompt, for example a buzz sound or a series of question marks ("?????"), the last word pair seen (the test word pair as opposed to the priming word pairs), in this example BARN DOOR, has to be spoken aloud. Interstimulus intervals are in the order of 1000 ms, as is the interval between the test word pair and the prompt to speak. All spoken responses are recorded. Every now and then a word pair like BARN DOOR will be mispronounced as DARN BORE, as a result of phonological priming by the preceding word pairs. At the time I was only interested in easily classifiable speech errors of specific kinds, therefore I ignored all cases that presented difficulties in classification. But I kept the recordings. So recently, I returned to these recordings to see whether they lend themselves for testing the above predictions. I attempted to make a very narrow transcription, by listening over and over again to all cases where the responses deviated from being fluent and correct. I found a number of clear cases of both feature anticipations, and ungrammatical errors (Figure 2).

Although feature errors apparently do occur (as observed also in spontaneous speech, for example by Fromkin 1973), they indeed were found to be relatively rare as compared to whole-segment errors: 25 feature errors against 182 errors involving whole segments. Similarly, speech errors violating the phonotactical rules

Feature anticipations:

kɑlm dɛŋk > tɑlm dɛŋk

bo:s χɑns > po:s χɑns

bɛil χɛit > pɛil χɛit

füt χe:w > föt χe:w

Ungrammatical sound errors:

fɛit χɑut > χfɛit χɑut

bɛil χɛit > χmχbɛil χɛit

füt χe:w > χχffit χœyw

pɑf kis > fkpɑf kis

Figure 2. Examples of 'feature anticipations' and phonototactically 'ungrammatical' speech errors, found in an experiment eliciting spoonerisms. See text.

of the language do occur, but are also relatively rare. I counted 40 violations of phonotactical rules, against 207 phonotactically regular errors.

These data were collected by careful transcription of the speech utterances elicited in the experiment. But if, as stated by Hank Truby, we, including linguists and speech researchers, and thus also including the present author, are "irrefragably conditioned" by our familiarity with the letters of the alphabet, then these data can not be trusted without further evidence. There is a real possibility that these data are strongly biased in favour of speech errors involving whole phonemes and in favour of phonotactically regular speech errors. One way to circumvent this problem is to measure articulatory movements in an experiment eliciting speech errors.

5. Measuring articulatory movements during speech errors

Goldstein, Pouplier, Chen, Saltzman, and Byrd (2007) measured articulatory movements during speech errors. Speech errors were elicited by having subjects repeat two-word phrases with alternating syllable onset consonants, like "top cop", at three different speech rates. Movements of the tongue tip and the tongue dorsum were measured with an electromagnetic mid-sagittal articulometer (EMMA, Perkell, Cohen, Svirsky, Matthies, Garabieta, & Jackson 1992), which allows tracking the movements of particular flesh points by means of small transducer coils attached to these points. Figure 3 gives two examples of registrations obtained with this method.

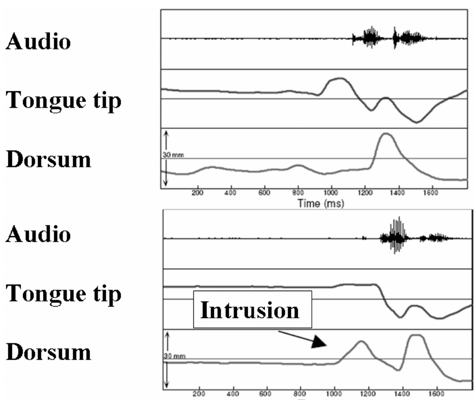

Figure 3. Two examples of registrations obtained in an experiment eliciting speech errors, and measuring articulatory movements (Goldstein et al., 2007). In each example the first line gives the audio signal, the middle one the movement of the tongue tip, and the lower one the movement of the tongue dorsum. Top: error free token of the utterance "tab cab". Bottom: intrusion of dorsum movement during "tab cab".

One should note that in Figure 3, if we compare the error-free token of "tab cab" (top panel) with the token containing an intrusion (lower panel), clearly the intrusion of the tongue dorsum movement does not replace the tongue tip movement. Both movements, one from the /t/ and one from the /k/, are made simultaneously. The pattern obtained constitutes a blend between the two speech sounds. Note also that the "speech error" in this case is not audible: The dorsum movement hides behind the tongue tip movement. However, if a full tongue tip movement would intrude on the pronunciation of a /k/, there would be an audible speech error. Such cases were also found. If a tongue tip movement would be substituted by a tongue dorsum movement, or vice versa, we would get a speech error that could be interpreted as one phoneme being substituted by another phoneme. Such substitutions also occurred, but were found to be relatively rare. Only 12% of all errors (full or partial) were substitutions, 79% were intrusions, and 9% were reductions. These data may come as a surprise to those who believe that speech encoding involves a level of abstract unanalyzable phonemes. Apparently, speech errors where whole phonemes are substituted by other whole phonemes are relatively rare. Interestingly, intrusions are far more frequent than reductions.

Goldstein et al. also find that in many, even most, cases intrusions and reductions are not complete but partial. 70% of all errors are partial (intrusions or reductions), 30% are full. It is noteworthy that, from a phonemic point of view, all complete and partial intrusions and reductions, audible or inaudible, are in fact blends between "phonemes": Two different phonemes, or at least articulatory movements belonging to two different phonemes, are inadvertently spoken simultaneously. All such speech errors, that is the majority of speech errors in this experiment, are ungrammatical from a phonological point of view. The fact that full or partial intrusions are far more frequent than full or partial reductions, may come unexpected for those who believe that speakers tend to minimize articulatory effort (For example, Lindblom 1990), but is easily accommodated by the theory of "Articulatory Phonology" (Browman & Goldstein 1992).

These findings confirm earlier evidence obtained by Mowrey & MacKay (1990), who found blends of speech sounds in electromyographic measurements on articulatory muscles, during an experiment eliciting speech errors, and by Frisch & Wright (2002), who found blends of voiced and voiceless fricatives in acoustic measurements in an experiment eliciting exchanges between [s] and [z]. The evidence by Mowrey & MacKay (1990), Frisch & Wright (2002), and Goldstein et al. (2007), suggests that observations by students of speech errors are flawed. They may have been filtered by the researchers' thorough familiarity with the letters of the alphabet. This new evidence on speech errors can be explained without assuming that the mental production of speech involves a level of speech encoding in which abstract unanalyzable phonemes are the basic units. It rather suggests that speech encoding involves a level where the units are articulatory gestures. Also, these gestures do not appear to be all-or-none, but are variable in strength under the influence of the environment. They can compete with each other in ways that are not licensed by the phonological structure of the language, as it is commonly perceived by phonologists.

Of course, the evidence by Goldstein et al. does not constitute proof that there is no level of speech encoding with unanalyzable phonemes as its basic units. Possibly their technique for eliciting speech errors favours slips on a lower level of control, whereas speech errors in spontaneous speech may often involve unanalyzable phonemes as units. Or phonemes may play a different role in speech preparation than we have thought. We have seen earlier that there is experimental evidence pointing at some form of psychological reality of unanalyzable phonemes (Wheeldon & Levelt 1995, Roelofs 1999). But the results by Goldstein et al. do throw some doubt on the standard view of speech errors as the results of misordering unanalyzable phonemes. It should also be noted that the results obtained by Wheeldon & Levelt (1995) and Roelofs (1999) do not pertain to ordering and misordering phoneme-like units, but do point at the inherent segmentability of the speech stream, and the identifiability of the resulting speech segments.

6. What is the origin of the segmentability of speech?

If we listen to fragments of speech shorter than what we normally consider to be a speech sound, going from early to late through the audio signal of a spoken word form, in most cases we can easily determine where one speech sound ends and the next begins. Speech, at least in the canonical pronunciation of the sound forms of a language, appears to be inherently segmentable. If, as suggested by the results of Goldstein et al., the planning units of speech are not phoneme-sized segments, but rather articulatory movements, this is not a matter of course. The reason is that what we normally call a speech sound, generally involves more than a single articulator, for example the tongue dorsum, the lower jaw, and the vocal cords for the /k/, and for each articulator more than a single movement, for example an opening and a closing movement. If the movements of different articulators were not temporally coordinated such that they are more or less synchronized, speech would not be so easily segmentable. Apparently, as all researchers know who have studied the movements of different articulators during speech production, movements of different articulators are indeed more or less synchronized, and slight deviations from this synchronization may be functionally relevant, causing for example the difference between the presence or absence of aspiration in languages where this difference is distinctive.

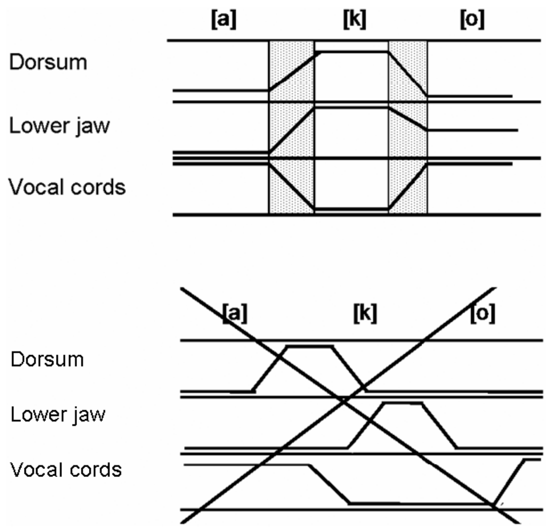

Figure 4. Schematic examples of synchronized (top) and not-synchronized (bottom) articulatory movements. The synchronized case would be more easily auditorily segmentable. The not-synchronized case is, in fact, not observed in reality. It seems to be ruled out by some property of speech production.

The synchronization and lack of synchronization between movements of different articulators is schematically exemplified in Figure 4. Those who believe in abstract unanalyzable phonemes as the underlying units of speech production, may believe that synchronization of articulatory movements is only natural, because this is required to express the underlying phonemes auditorily. But if we take seriously the earlier evidence that the planning units of speech production are not phonemes but rather articulatory movements, we should consider the question what then is the origin of the temporal coordination of articulatory movements, and thus the origin of the segmentability of speech. One answer to this question comes from the "Articulatory Phonology" of Browman and Goldstein (1992; see also Goldstein et al. 2007). According to this line of thinking the temporal coordination of movements of different articulators is explained from properties of speech production itself: It is easier to combine different articulatory gestures than to program these independently: Different gestures have the tendency to be "in phase" with each other, because different articulators are coupled.

A quite different answer to the same question, but one that could be simultaneously valid, is provided by Ohala (1992). Ohala looks at the processes that lead to a particular structure of the sound forms of a language as a self-organizing system striving towards optimal auditory discriminability of these sound forms. He imagines a system that consists of (a) human speech organs with all their mechanical and neuromuscular constraints, (b) a human hearing system, with its constraints, and (c) a control program that controls the speech organs, listens to the output of the hearing system, and has the possibility to learn with trial and error to comply with certain criteria. This system may, for example, be set up to develop by trial and error a set of a few hundred of different pronounceable short sound forms that are optimally discriminable. Ohala's argument is that in the reiterant process changing the articulation of the sound forms in order to make them optimally discriminable, synchronization of articulatory movements will arise naturally, simply because each other solution will lead to less discriminable sound forms. To bring this argument closer to real language communities: the synchronization of articulatory gestures may be considered to arise naturally from the tendency in a language community to make the sound forms of the language optimally discriminable. Because of the synchronization of different articulatory gestures, the sound forms of speech naturally organize themselves as an alternation of very brief periods of transition, where much changes simultaneously, and longer more or less steady-state intervals, where very little changes. This alternation is the basis of the inherent segmentability of speech. Obviously, segmenting the stream speech is easiest when the combined articulatory movements are relatively fast and the steady-state segments in between relatively long. Segmenting may become more problematic with diphthongs and approximants like /ʁ/, /w/, /h/and /j/. This is why my first year students in a phonetics class each year failed to tell me how many segments are to be counted in the Dutch word "eieren" (/ɛiəʁə/). The answers vary from 3 to 6.

7. Winding up

The current enterprise started with two questions:

1. What is the origin of our skill to read and write the sound forms of languages with alphabetic characters?
2. Why is that so difficult?

The considerations and arguments given above suggest the following answers to these questions: The origin of our skill of alphabetic writing is the inherent segmentability of speech. This segmentability stems from the synchronization of different articulatory gestures during pronunciation, which in its turn may be a function of both the production system, preferring to let different articulatory gestures be "in phase" with each other, and the perception system, preferring optimally discriminable sound forms.

Learning to read and write is often difficult because the fact that speech is inherently segmentable, does not necessarily mean that all language users indeed easily segment the sound forms of their language. Very likely, language users differ in the ease with which they have access to the segmented sound stream. The skill of segmenting the speech stream is a prerequisite for phonemic awareness and phonemic awareness for learning to read and write alphabetically. Although it has been shown that children are sensitive to rhyme before they have learned to read and write, further phonemic segmentation is far more difficult and probably only develops from learning to read and write in an alphabet (Bradley & Bryant, 1978; Mutter, Hulme, Snowling & Taylor 1998). For some the segmenting skill may come fast and naturally in early life, but for many others it is a skill that is not easy to learn. No wonder that phonemic awareness is often explicitly taught as part of the lessons in reading and writing.

Learning to read and write alphabetically is so difficult, precisely because, before this skill has developed, letter-like phonemes do not pre-exist in all minds, at least not as units that can be easily brought to awareness (the earlier discussed results by Wheeldon & Levelt 1995 and Roelofs 1999 suggest that unanalyzable phonemes do have some role to play in speech encoding, but if so, this role remains hidden from awareness). In the conventional spelling there often are uncertainties that are resolved arbitrarily, because there does not appear to be a principled solution. It is practical that in English "p" in "pit" differs from "b" in "bit", because the difference in spelling corresponds with a difference in sound, which corresponds to a difference in meaning. But "p" in "spit" does not contrast with "b" in "*sbit", and in fact sounds more like "b" in "bit" than like "p" in "pit". The spelling "spit" instead of "*sbit" seems entirely arbitrary. If it were not for the sake of reading and writing alphabetically, there would be little reason to ask questions about differences and similarities between words such as "pit", "bit" and "spit".

The problems in learning to read and write often are aggravated by the many inconsistencies in the orthographies of languages. Those who learn to read and write English, at some stage may become aware of the fact that the "c", "cc", "ck", "cch", and "k" in respectively "bacardi', "baccarat", "back", "bacchanal" and "bake" all have the same pronunciation /k/, whereas the "c" and "cc", in respectively "ace", and "bacciferous" are pronounced as /s/, and /ks/. It is noteworthy, though, that such inconsistencies themselves are no problem for many adult users of the orthography. They have circumvented the problem by having learned how to read and write words, not sounds. Such a strategy may help those people who have difficulties in segmenting speech, but have good memories. But here also, language users seem to differ considerably. A simple, systematic and transparent orthography would be particularly profitable to those who have problems memorizing the spelling of many different words, and would not be harmful to others. This may be a consideration in designing spelling changes.

In conclusion, then, the current considerations and arguments suggest that phonemes in the sense of unanalyzable, discrete, ordered or misordered building blocks of sound forms, are not universal properties of the language faculty in speakers and listeners. In as far as discrete phonemes have some psychological reality that the language users themselves may be aware of, this is only so for those who learn or have learned to read and write alphabetically. Yet, speech is inherently segmentable for those who set their minds to it, and this provides the basis for our capacity to learn to read and write in an alphabet. In this sense, phonemes come from letters, not letters from phonemes.

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