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Orthographic Systems and Skilled Word Recognition Processes in Reading

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The process of recognizing printed words has been studied for many years, yielding several important models of word recognition in reading. These models provide a variety of descriptions of the word recognition process, given different assumptions regarding the structure of the lexical system. Yet what all models have in common is the recognition that reading involves the processing of orthographic, phonological, semantic, and morphological information. Since this information is conveyed differently in each language, the question of how the reader's linguistic environment shapes the reading process is of primary importance. This chapter focuses on the relations between the specific characteristics of different orthographic systems and skilled reading. The starting point is an outline of the dimensions on which orthographic systems differ from each other (see also Treiman & Kessler, this volume). This discussion will be followed by a detailed description of what skilled reading entails. As such a description is necessarily model-dependent, two main approaches to skilled reading will be presented. As a final step, the discussion will outline how proficient reading is shaped by the structure of the language and its orthographic system.







Overview of Writing Systems

In contrast to speech, which is an emerging property of human biology, orthographic systems are a human invention, just as the wheel is. All orthographies, whether alphabetic, syllabic, or logographic, were invented a few thousand years ago with the sole purpose of communicating spoken language in graphic form. How language was eventually represented graphically is of considerable interest.

One interesting solution for the graphic representation of language is the ancient Egyptian hieroglyphic script. Hieroglyphs were composed mainly of ideograms, which are pictorial signs depicting objects or actions. The hieroglyphic script is interesting because it demonstrates the futility of a representational system in which semantic concepts and words are directly represented by an analog schematic picture. The clear disadvantage of such a system is that abstract semantic concepts cannot be represented, and even for more concrete concepts, representation is not always unequivocal. This is why ideograms could not suffice as an efficient graphic communication system in written Egyptian, and consequently a large number of the old Egyptian hieroglyphic signs were alphabetic phonograms that depicted phonemes (basically consonants) and had no relations whatsoever to the concept to be represented in print. These phonograms are considered to be *the Egyptian alphabet*, and include 24 letter-signs. In addition to the 24 letter signs there were also two-phoneme and three-phoneme signs, many of which had a meaning of their own and represented individual words. In this case, however, they were completed with a stroke, the so-called *ideogram sign*, to indicate that the designated word corresponded to the pictorial value of the sign. Additionally, sometimes the two- and three-letter signs were given *phonetic complements* – one-letter signs that repeated all or some of their sound value. The purpose of these complements was to indicate that the signs were phonograms, not ideograms. Examples of Egyptian hieroglyphic signs are presented in table 15.1.

The history of the Egyptian hieroglyphic script thus provides a unique insight into the nature of this wonderful invention that we call orthography. Contrary to the layman's perception that the Egyptian script presents a viable option for representing objects and actions pictographically, it actually teaches us just the opposite lesson – namely that any human writing system cannot do without phonographic signs.

Table 15.1 Examples of Egyptian hieroglyphs. The First Three Hieroglyphs Represent General Concepts, Whereas the Last Three Belong to the Egyptian Alphabet

		man
		god, king
		bird, insect
	b	foot
	n	water
	m	owl

Orthographic systems can therefore be contrasted with pictographic systems. Pictures and many signs (e.g., a picture of a dog, an arrow sign) represent meaning directly and are characterized by nonarbitrary relations between graphic sign and transcribed meaning. The visual shape of a graphic sign per se conveys its meaning, and often this meaning can be recovered, at least to some extent, without prior explicit teaching. In contrast, for written words in any language, the relations between graphic signs and meaning are arbitrary. This arbitrariness derives precisely from the fact that the graphic signs convey only phonological units systematically, and that the mapping of phonological units into semantic meaning is indeed arbitrary.

Although in every written language the graphic signs represent phonological units, the manner in which orthographies represent their spoken language depends on the characteristics of each language. Writing systems can be distinguished by the size of the linguistic units that the orthographic units transcribe: phonemes, as in English; syllables (moras), as in Japanese Kana; or morphosyllables, as in Chinese characters. What defines the unit of representation is mainly the efficiency of the representational system in terms of memory constraints or processing limitations. For example, in the Japanese syllabic Kana orthography, the graphemes represent the 116 permissible syllables in the Japanese language. (There are several possible ways of counting the number of permissible syllables in Japanese, and the above assessment represents just one of them.) This number is fairly small, given the constraint that Japanese has 14 consonants and 5 vowels, and its syllabic structure is constrained to vowel or consonant-plus-vowel combinations. The most efficient representational system is therefore a system that provides a grapheme for each of these syllables, since learning and memorizing 116 graphic signs is not very difficult. In sharp contrast, the syllabic structure of English is far more complex (see Akmaï-jian, Demers, Farmer, & Harnish, 2001, for a detailed description). Not only does English have 24 consonants and 15 vowels, but the permissible syllables have many possible structures (e.g., CV, VC, CVC, CCVC). This has immediate implications not only for the number of permissible syllables in the language that would require an independent symbol – about 15,000, but also, more importantly, for the ability of English native speakers to retrieve the word's syllables. The division of many English words into syllables is controversial, as syllabic boundaries are not well defined (e.g., *dagger*). These words contain ambisyllabic segments in which a clear break does not exist, and therefore different parsings into syllables can be suggested (see Kahn, 1976). For these reasons, therefore, a syllabic orthography would never work for English speakers. Learning and memorizing thousands of distinct graphic signs is an exhausting task, and matching signs to several syllabification possibilities rather than one unequivocal solution would be a very slow cognitive process. This is one reason why orthographic units in English transcribe phonemes rather than syllables.

As described above, Japanese Kana and English are alphabetic systems, which differ in the size of the sublinguistic units represented by the orthographic units. Indeed, most orthographic systems are alphabetic, and the graphic signs represent subsyllabic or syllabic linguistic units. Some orthographic systems, however, have adopted an entirely different approach for representing spoken language. Perhaps the most notable example are logographic orthographies such as Chinese in which the graphemic structure represents meaningful morphemes and not sublinguistic phonological units. But even in Chinese

90% of the characters are phonetic compounds (although not necessarily consistent) and only 10% are semantic determiners whose purpose is to differentiate between the many homophones existing in that language (DeFrancis, 1989).

Yet another transcription strategy was adopted in the logographic Japanese Kanji and Korean Hanja. As will be described in detail later on, both languages in addition to their phonographic system imported the Chinese logographs. However, the logographic symbols were meant to represent meaningful morphemes with a pronunciation differing from the one they had in their original language, since they were imported into a different spoken language, and so their phonological components were distorted. For these reasons, phonographic notations were added to the characters in both languages for the purpose of facilitating reading. In Japanese, some Kanji words are printed with a phonetic transcription next to them (Furigana), which provides the reader with the necessary cues for pronouncing the logographs. Furigana is used mainly for children and foreigners learning Kanji. In Korean, the logographic Hanja characters are mixed inconsistently with an alphabetic script, the Hangul, to facilitate reading.

To summarize, writing systems have evolved to represent various sublinguistic units of the spoken language (phoneme, syllable, morphophonemes). Although writing systems clearly are not phonographic to the same extent, they all contain at least some cues to the phonological structure of printed words. The main implication of this is that writing systems were not designed (and indeed could not have been designed) to transcribe units of meaning directly without some reference to their phonological form. This is because languages are productive by nature, new words are constantly being invented, and meanings evolve with time. The only form of orthographic system that can in principle deal with language productivity is a spelling system that transcribes subword linguistic units, thereby specifying a set of rules for representing novel words (Mattingly, 1992).

Having outlined the characteristics of the orthographic systems of natural languages, in the next section I will discuss how orthographic information is processed by proficient readers during reading.

Models of Skilled Reading

Two major theories should be considered in the context of modeling skilled reading: the dual-route theory (e.g., Coltheart, 1980; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Paap & Noel, 1991; Paap, Noel, & Johansen, 1992; Zorzi, Houghton, & Butterworth, 1998), and the single-route strong phonological theory (e.g., Frost, 1998; Lukatela & Turvey, 1994a, 1994b; Van Orden, Pennington, & Stone, 1990). The dual-route theory suggests a lexical architecture in which an orthographic input lexicon plays a major role. The dual-route theory has generated various models in the last three decades, which differ in their architectural assumptions. For example, the dual-route cascaded (DRC) model of Coltheart et al. (2001) and the model of Zorzi et al. (1998), are both dual-route models. However, the former assumes local representations, whereas the latter assumes that words are represented as distributed patterns of activation. What all these models have in common is the assump-

tion that reading involves an interplay between prelexical phonological computation, on the one hand, and visual orthographic processing, on the other. Note, however, that dual-route models generally assume that phonological computation is relatively slow and lags behind orthographic processing. Thus, whereas beginning readers are mostly engaged in prelexical grapheme–phoneme computations, converting letters to phonemic segments to recover the printed word's phonology piece by piece, proficient readers can make use of fast, direct connections between orthographic representations and the phonological output lexicon, or between the orthographic forms and semantic meaning. Thus, skilled reading is regarded as the result of acquiring orthographic representations of printed words through repeated exposure to these words during reading acquisition. In this view, the recognition of a printed word in most cases involves fast access to well-established orthographic representations, which lead to the activation of full phonological structures and/or the relevant semantic features. Generally stated, the dual-route model defines the acquisition of reading skills as the ability to bypass mechanisms that convert orthographic subunits into phonological subunits, thereby relying on direct connections between orthographic representations to meaning.

The main alternatives to the dual-route theory are the strong phonological models of reading (Lukatela & Turvey, 1994a, 1994b; Van Orden et al., 1990; and see Frost, 1998, for a review and a detailed description). The critical difference between the strong phonological view and the dual-route theory lies not in terms of architectural differences such as distributed versus localist connectionist frameworks. It lies in the relative involvement of the orthographic lexicon, on the one hand, and the nonlexical route, on the other hand, in the process of word recognition. Although the primary models that adopt a strong phonology stance are not instantiated models, they all contend that, given the phonological nature of human natural languages, the core lexical representations of words are phonologically defined. In this view, visual word recognition involves mostly the phonological, not the orthographic, lexicon. Strong phonological models regard the initial process of reading as a process of converting letters or letter clusters into phonemes or syllables (unambiguous letters first), using prelexical conversion rules (or relying on grapheme–phoneme activation in a connectionist architecture). Thus, these models suggest that phonological computation is mandatory, and lexical search consists of registering and finding stored phonological units. As will be demonstrated in the following discussion, in some orthographies the computation of phonology from print is by no means simple, and often this process results in an impoverished phonological code. Therefore, strong phonological models of reading define the acquisition of reading skills along three independent dimensions: (1) the speed of the assembly process, (2) the size of the computed orthographic units, and (3) the efficiency of accessing the lexicon through impoverished phonological information.

Regarding the speed of the assembly process, the strong phonological model of reading views the acquired competence of skilled readers as their ability to complete the initial cycles of assembly in minimal time. Thus, with increased exposure to reading, the beginning reader's efficiency in computing a prelexical phonological representation increases, making it possible to generate a skeletal phonological structure more quickly, thus leading to fast lexical access (e.g., Berent & Perfetti, 1995; Lukatela & Turvey, 1994a, 1994b).

The second dimension involves the size of the computed units. Although in alphabetic orthographies single letters generally represent single phonemes, there are quite a few cases in which phonemes are represented by letter clusters. This necessarily introduces additional complexity into the relations between spelling and phonology, since the prelexical computation process needs to take the adjacent letters into account in order to produce the correct phoneme. The skilled reader of English needs to know, for example, that *c* before *e* is pronounced /s/, but before *o* it is pronounced /k/, or that *ough* could be /o/ or /off/, but is never the primary phonemic transcription of each letter. The acquisition of reading skills can therefore be characterized as an increased ability to convert larger letter clusters into phonemic clusters, rather than depending on single letter-to-phoneme conversion. Ultimately, it could be possible, in principle, to convert whole printed words into whole phonological units. This is, in fact, the notion of direct connections between orthographic representations and the phonological output lexicon that forms the conceptual basis of dual-route models (cf. also Ehri, this volume). However, strong phonological models view the process of learning to read as a fine-tuning of *optimal-sized* units (larger than the single letter but smaller than the whole word), given the specific characteristics of the reader's orthography. The proficient reader learns to parse the printed word into letter units that allow fast conversion into a preliminary phonological representation. Indeed, there is a large body of evidence suggesting that while beginning readers engage in simple grapheme-phoneme conversion strategies, skilled readers also use larger grain-sized units such as bodies and rhymes (e.g., Brown & Deavers, 1999; Goswami, Gombert, & de Barrera, 1998).

The third dimension of reading competence involves an acquired efficiency in accessing the lexicon with impoverished phonological information. What makes lexical access fast, in spite of the extreme richness of lexical information, is the ability to access an entry or activate a word node with the accumulation of phonological information that is not necessarily full or complete. However, the ability to access the lexicon with only partial phonological information is a learned process involving prolonged exposure to printed words. According to this view, beginning readers are limited to a *detailed* analysis of the printed word before lexical access is achieved, whereas skilled readers can recognize the same word *with a relatively impoverished representation* (Frost, 1995; and see Frost, 1998, for a detailed discussion). As I will discuss below, different orthographies impose different constraints on the ability to generate a detailed and accurate phonological representation.

Orthographic Depth and How Phonology Is Represented in Different Orthographies: The Case of English, Hebrew, and Serbo-Croatian

As all orthographies represent spoken forms, one major determinant of orthographic systems concerns the specific way they represent the phonological characteristics of the language. When the writing system is alphabetic, and letters represent the phonemes of

the language, some opacity may exist in the representational system. The transparency of the relation between spelling and phonology varies widely between orthographies. This variance can be attributed to phonological or morphological factors. Opacity may be present simply because the spoken language has assimilated novel phonetic variations during its history, whereas the letters in the orthographic system have remained unchanged. This will necessarily lead to some ambiguity in the relations between letters and phonemes. In addition, in some languages morphological variations are captured by phonologic variations. The orthography, however, is designed to preserve and convey the morphologic information. Consequently, in many cases, similar spellings used to denote the same morpheme will have different phonologic forms. Consider, for example, the English words “heal” and “health.” These words are similarly spelled because they are morphologically related, both containing the base-morpheme *heal*. However, since the morphological derivation *health* resulted in a phonologic variation (the phoneme /i/ turning now to /e/), the orthographic cluster “ea” represents in the two words two distinct phonemes. Alphabetic orthographies thus can be classified according to the transparency of their letter to phonology correspondence. This factor is usually referred to as “orthographic depth” (Klima, 1972; Liberman, Liberman, Mattingly, & Shankweiler, 1980; Lukatela, Popadic, Ognjenovic, & Turvey, 1980; Katz & Feldman, 1981). An orthography that represents its phonology unequivocally following simple grapheme–phoneme correspondences is considered *shallow*, while an orthography in which the relation of orthography to phonology is more opaque is labeled *deep*. Orthographic depth is often regarded as a continuum, and in this view languages may be aligned one next to the other where one language would be considered deeper than another but shallower than a third one (e.g., Frost, Katz, & Bentin, 1987). In the following I will discuss a few languages with reference to their orthographic depth.

English

English is regarded as an example of a deep orthography. The main source of complexity in English derives from its rich vowel system, about 15 vowels, which are represented by fewer graphemes. In principle, the complexity of grapheme–phoneme correspondence can generally be defined in terms of the ease of computing a phonological representation from print, given the transparent or opaque mapping of spelling patterns into phonology. The degree of transparency arises, however, from two different factors. The first factor concerns the conformity of a given letter cluster to grapheme–phoneme correspondence rules. This factor is labeled *regularity*. For example, the pronunciation of words like *yacht* or *chef* cannot be simply computed using the grapheme–phoneme conversion rules of English. Thus, *yacht* and *chef* are considered irregular. The second factor is *consistency*. Consistency involves the uniqueness of pronunciation of an orthographic body. Thus, if two words are spelled similarly but pronounced differently (such as MOTH–BOTH), the letter cluster OTH is considered inconsistent (Glushko, 1979; Patterson & Coltheart, 1987). According to this analysis, words can be regular but inconsistent, or irregular but consistent. English orthography contains many words that are either irregular or inconsistent; this is why English is called a deep orthography.

Hebrew

In Hebrew, letters mostly represent consonants while most of the vowels can optionally be superimposed on the consonants as diacritical marks ("points"). The diacritical marks are, however, omitted from most reading material, and can be found only in poetry, children's literature, and religious scriptures. Since different vowels may be inserted into the same string of consonants to form different words or nonwords, Hebrew unpointed print cannot specify a unique phonological unit. Therefore, a printed consonant string is always phonologically ambiguous and often represents more than one word, each with a different meaning. In this context, the depth of the Hebrew orthography is different in character from that of English orthography. Whereas in English the opaque relations of spelling to sound are related to irregularity and/or inconsistency of letter clusters, in Hebrew opaque spelling-to-sound connections arise simply from *missing* phonemic information, mainly vowel information. Note that when the diacritical marks are presented in the text, Hebrew orthography is entirely shallow, as the phonemic structure of the printed word can be easily assembled using simple grapheme–phoneme conversion rules. The Hebrew alphabet is presented in Table 15.2.

Table 15.2 The Hebrew Alphabet. The Hebrew Letters א and V Stand for Glottal and Pharyngeal Stops, Respectively. K, m, p, c Have Different Forms When They Appear at the End of the Word

Hebrew print	Phonetic transcription
א	a
ב	b, v
ג	g
ד	d
ה	h
ו	o, u, v
ז	z
ח	x
ט	t
י	I, y
ך / כ	k, x
ל	l
ם / מ	m
ן / נ	n
ס	s
ע	V
ף / פ	p, f
ץ / צ	<u>ts</u>
ק	k
ר	r
ש	<u>sh</u>
ת	t

The depth of Hebrew orthography is evident in yet another feature. Several consonants (mainly, /k/, /t/, /x/, /v/, and glottal /a/), have two letters representing them. In ancient Hebrew these letters depicted a phonetic distinction that is absent in modern Hebrew. Note, however, that the opacity between letters and phonemes is mainly relevant for correct spelling rather than for reading. This is because, although a given phoneme may be written in two different ways (as in the case of C and K in English), the reading of the printed letter is entirely consistent.

English and Hebrew are therefore considered deep orthographies, but as shown above, their depth derives from different sources. It seems clear, then, that the opacity between orthography and phonology cannot be adequately described through the one-dimensional factor of labeling languages simply as “deep” or “shallow.” Rather, one should consider also the *direction* of opacity: Is it in the mapping of orthography to phonology, or is it in the mapping of phonology to orthography? Consider, for example, the French orthographic system. French has transparent relations between print and phonology. Thus, the grapheme–phoneme conversion rules in French specify the phonology of printed words almost unequivocally. There are, however, several possible spellings for a given phoneme (e.g., *o*, *au*, *eau* may represent the vowel /o/). Thus, the mapping of phonology to spelling is opaque in French. A similar problem arises in pointed Hebrew: The orthography specifies the phonology unequivocally, but since several consonants have two letters representing them, the mapping of phonology to spelling is opaque. In languages such as English, opacity exists in both directions: from print to phonology as well as from phonology to print. Some languages, such as Spanish, Italian, and Serbo-Croatian are entirely transparent in both directions. The implication of directionality of opacity for reading performance was found to affect visual word recognition (e.g., Stone, Vanhoy, & Van Orden, 1999). Stone and his colleagues labeled this factor as *feed-forward* versus *feed-backward consistency*, demonstrating that both forms of consistency affect visual word recognition in English (see also Van Orden & Kloos, this volume).

Serbo-Croatian

In Serbo-Croatian, aside from minor changes in stress patterns, phonology almost never varies with morphologic derivations. In the nineteenth century, a new orthographic system was imposed in the former Yugoslavia, designed to represent directly the surface phonology of the language. In this system each letter denotes only one phoneme, and each phoneme is represented by only one letter. Thus, the reading of any given letter in Serbo-Croatian cannot change in different orthographic contexts. In contrast to English, Serbo-Croatian has only five vowels /a/, /e/, /i/, /o/, /u/, without any phonetic variations. Similarly, all consonants in Serbo-Croatian are read unequivocally, and adjacent letters cannot change their reading. Even imported proper nouns are printed in Serbo-Croatian so that their original orthographic structure is not preserved, and the letters employed reflect the phonemic structure of these nouns. Correct reading in Serbo-Croatian thus involves the mere application of simple grapheme–phoneme rules. Even a nonspeaker of the language can easily learn to read Serbo-Croatian after memorizing the phonemic

transliteration of the 33 letters of the alphabet. Thus, Serbo-Croatian is often presented as an example of an extremely shallow orthography.

Orthographic Depth and Visual Word Recognition

The effect of orthographic depth on reading strategies has been the focus of extensive research (e.g., Baluch & Besner, 1991; Besner & Smith, 1992; Frost et al., 1987; Katz & Feldman, 1983; Tabossi & Laghi, 1992; Ziegler, Perry, Jacobs, & Braun, 2001; see also Seymour, this volume). In general, the argument revolves around the question of whether differences in orthographic depth lead to differences in processing printed words. What is called the Orthographic Depth Hypothesis suggests that it does. The Orthographic Depth Hypothesis suggests that shallow orthographies can easily support a word-recognition process that involves the printed word's phonology. This is because the phonologic structure of the printed word can be easily recovered from the print by applying a simple process of phonological computation. The correspondence between spelling and pronunciation in these orthographies is simple and direct, so that a reader of these orthographies can easily assemble an accurate representation of the word intended by the writer. In contrast, in deep orthographies like English or Hebrew, readers are encouraged to process printed words making use of larger units.

The specific predictions from the Orthographic Depth Hypothesis refer mainly to the way a printed word's phonology is generated in the reading process. These predictions depend, however, on the specific model of skilled reading that is embraced, whether a dual-route model or a strong phonological model. Note again that each model can be described using connectionist or nonconnectionist terminology. Described from the dual-route viewpoint, since readers of shallow orthographies have simple, consistent, and fairly complete connections between graphemes and subword pronunciation, they can recover most of a word's phonological structure prelexically by assembling it directly from the printed letters. In contrast, the opaque relation of letter clusters and phonemes in deep orthographies prevents readers from using prelexical conversion rules. For these readers, a more efficient way of generating the word's phonologic structure is to rely on fast visual access of the lexicon and retrieve the word's phonology from it. Thus, according to the dual-route framework, phonology in a shallow orthography involves mostly prelexical computation, whereas in a deep orthography, phonology is retrieved from the phonological output lexicon following activation of the visual lexicon.

The strong phonological theory provides different descriptions of similar processes. The theory assumes that prelexical phonological computation is a mandatory process that is automatic and very fast. In shallow orthographies, prelexical computation produces an accurate phonological representation of the printed word. In contrast, in deep orthographies, because of the opaque relations of graphemes and phonemes, this initial phase can only provide the reader with an impoverished phonological representation. This representation, however, is shaped by lexical knowledge to produce the correct pronunciation. Thus, top-down shaping of the prelexical computation product leads to a detailed phonological representation.

From an historical perspective, two versions of the Orthographic Depth Hypothesis have been offered. What can be called the *strong* Orthographic Depth Hypothesis claimed that in shallow orthographies the complete phonological representation is derived *exclusively* through prelexical translation of letters or letter clusters into phonological units. According to this view, readers of shallow orthographies perform a phonological analysis of the word based only on knowledge of these correspondences. Rapid naming, then, is a result of this analytic process *only*, and does not involve any lexical information (see Katz & Frost, 1992, for a discussion).

It is easy to show that the strong form of the Orthographic Depth Hypothesis is untenable. It is patently insufficient to account for pronunciation, even in shallow orthographies like Spanish, Italian, or Serbo-Croatian, reverting only to the process of prelexical phonological computation. Some lexical shaping is always necessary because these orthographies do not represent syllable stress and, even though stress is often predictable, this is not always the case. For example, in Serbo-Croatian, for two-syllable words the stress is always placed on the first syllable, but this is not always true for words of more than two syllables. These words can be pronounced correctly only by reference to lexically stored information. The issue of stress assignment is even more problematic in Italian, where stress patterns are much less predictable. In Italian many pairs of words differ only in stress that provides the intended semantic meaning (Colombo & Tabossi, 1992).

In the light of these arguments, a weaker version of the Orthographic Depth Hypothesis gained increasing support. According to the weak version of the Orthographic Depth Hypothesis, the phonology needed for the pronunciation of printed words in any orthography may involve both prelexical letter-to-phonology correspondences and lexical phonology. The differences between deep and shallow orthographies are mainly quantitative, not qualitative. From the dual-route perspective, in any orthography both prelexical and lexical processes are launched. In cascaded models such as the DRC model (Coltheart et al., 2001; Coltheart this volume), the two processes also exchange information. Whether or not prelexical processes actually dominate orthographic processing for any particular orthography is a matter of probability, given the demands the two processes make on the reader's processing resources (see Seidenberg, 1992, for a discussion). These demands are affected by the depth of the orthography. Prelexical analytic processes are more useful in shallow orthographies than in deep orthographies, whereas the opposite is true for lexical processes. From the perspective of the strong phonological view, phonology is always partly prelexical and partly lexically shaped. The involvement and need for lexical shaping depends, among other things on orthographic depth. Greater lexical shaping is required in deep than in shallow orthographies, and vice versa.

Empirical Evidence for the Orthographic Depth Hypothesis

Evidence relevant to the Orthographic Depth Hypothesis comes from experiments that investigate whether phonology is computed prelexically or whether it is lexically shaped.

Typically, latencies and error rates for naming words are monitored, to find out whether the lexical status of a printed stimulus (whether it is a word or a nonword, and whether it is a frequent or infrequent word) affects its pronunciation. If phonology is assembled from print prelexically, smaller effects of the word's frequency should be expected than if phonology is lexically mediated. A second method of investigation involves monitoring semantic priming effects in naming (see Lupker, 1984, Neely, 1991, for a review). If pronunciation involves lexical phonology, strong semantic priming effects will be revealed in naming. In contrast, if pronunciation depends mainly on prelexical phonology, naming of target words should be facilitated only weakly by semantically related primes.

Evidence supporting the weak Orthographic Depth Hypothesis is abundant. Katz and Feldman (1983) compared semantic priming effects in naming and lexical decision in both English and Serbo-Croatian, and demonstrated that while semantic facilitation was obtained in English for both lexical decision and naming, in Serbo-Croatian semantic priming facilitated only lexical decision. Similarly, a comparison of semantic priming effects for word naming in English and Italian showed greater effects in the deeper (English) than in the shallower (Italian) orthography (Tabossi & Laghi, 1992). A study by Frost et al. (1987) involved a simultaneous comparison of three languages, Hebrew, English, and Serbo-Croatian, and confirmed the hypothesis that the use of prelexical phonology in naming varies as a function of orthographic depth. Frost et al. showed that the lexical status of the stimulus (its being a high- or a low-frequency word or a nonword) affected naming latencies in Hebrew more than in English, and in English more than in Serbo-Croatian. In a second experiment, Frost et al. showed a relatively strong effect of semantic facilitation in Hebrew (21 ms), a smaller but significant effect in English (16 ms), and no facilitation (0 ms) in Serbo-Croatian.

Frost and Katz (1989) studied the effects of visual and auditory degradation on the ability of subjects to match printed to spoken words in English and Serbo-Croatian. They showed that both visual and auditory degradation had a much stronger effect in English than in Serbo-Croatian, regardless of word frequency. These results were explained by extending an interactive model that rationalized the relationship between the orthographic and phonologic systems in terms of lateral connections between the systems at all of their levels. The structure of these lateral connections was determined by the relationship between spelling and phonology in the language: simple isomorphic connections between graphemes and phonemes in the shallower Serbo-Croatian, but more complex, many-to-one, connections in the deeper English. Frost and Katz argued that the simple isomorphic connections between the orthographic and the phonologic systems in the shallower orthography enabled subjects to restore both the degraded phonemes from the print and the degraded graphemes from the phonemic information, with ease. In contrast, in the deeper orthography, because the degraded information in one system was usually consistent with several alternatives in the other system, the buildup of sufficient information for a unique solution to the matching judgment was delayed, so the matching between print and degraded speech, or between speech and degraded print, was slowed.

The psychological reality of orthographic depth, however, is not unanimously accepted. Although it is generally agreed that the relation between spelling and phonology in different orthographies affect reading processes (especially reading acquisition), there is some disagreement about the relative importance of this factor. What is often

called “the Universal Hypothesis” argues that in all orthographic systems, print is processed essentially in the same way. The primary theoretical basis of the Universal Hypothesis is the dual-route architectural assumption that, in *any* orthography, words can easily be recognized through a fast visual-based lexical access that in most cases occurs before a phonologic representation has time to be generated prelexically from the print. In this view the primary factor determining whether or not the word’s phonology is assembled prelexically or addressed from the lexicon is word frequency. The Universal Hypothesis thus suggests that the relation of spelling to phonology should not affect the recognition of frequent words. Orthographic depth exerts some influence, but only on the processing of low-frequency words and nonwords, since such verbal stimuli are less familiar and their visual lexical access is slower (Baluch & Besner, 1991; Seidenberg, 1985; Tabossi & Laghi, 1992).

A few studies involving cross-language research support the Universal Hypothesis. Seidenberg (1985) demonstrated that, in both English and Chinese, naming frequent printed words was not affected by phonologic regularity. This outcome was interpreted to mean that, in logographic as in alphabetic orthographies, the phonology of frequent words is derived after the word has been recognized on a visual basis. Similar conclusions were offered by Baluch and Besner (1991), who investigated word recognition in Persian. In this study the authors took advantage of the fact that some words in Persian are phonologically transparent whereas others are phonologically opaque. This is because, in a way that is similar to Hebrew, three of the six vowels of written Persian are represented in print as diacritics and three as letters. Because fluent readers do not use the pointed script, words that contain vowels represented by letters are phonologically transparent, whereas words that contain vowels represented by diacritics are phonologically opaque (see Frost, 1995, for an identical manipulation in Hebrew). Baluch and Besner demonstrated similar semantic priming effects in naming phonologically transparent and phonologically opaque words of Persian, provided that nonwords were omitted from the stimulus list. These results were interpreted to suggest that naming both types of words followed lexical access.

A different approach to resolving this inconsistency in results was adopted in several studies that examined the grain-size of units employed by readers of deep and shallow orthographies. Thus, rather than seeking an all-or-none answer to the question of whether phonology is lexical or not, these studies contrasted beginning or proficient readers of deep and shallow orthographies by monitoring the size of the computed units they use in reading (e.g., Frith, Wimmer, & Landerl, 1998; Goswami et al., 1998; Ziegler et al., 2001). As explained above, the strong phonological model of reading considers skilled reading as an increased ability to convert larger letter clusters into phonemic clusters, rather than depending on single letter-to-phoneme conversion. Following the same logic, the Orthographic Depth Hypothesis would suggest that while readers of shallow orthographies can effortlessly convert graphemes into phonemes, readers of deep orthographies use larger-sized letter patterns to overcome the inconsistency in the letter-to-phoneme correspondence of their writing system. Note that this theoretical approach assumes that phonological computation underlies successful reading in all orthographies (see Share, 1995, for a discussion), and that orthographic depth merely affects the nature of the computation process, mainly the size of processing units.

This hypothesis was directly tested in a recent study by Ziegler and his colleagues (Ziegler et al., 2001). Ziegler et al. examined the grain-size of units employed by skilled readers in a deep (English) and a shallow orthography (German). The authors presented German and English speakers with identical words and nonwords in their native language, and found that the naming performance of readers of German was affected by the number of letters, whereas the naming performance of readers of English was affected by the words' bodies and rhymes. These results were interpreted to suggest that skilled readers of deep orthographies like English employ large-sized units in reading aloud, whereas skilled readers of shallow orthographies like German rely on minimal-sized units, mostly letters and phonemes.

Although most studies investigating the effect of orthographic depth on skilled reading monitored reaction time or error rates to visually presented words, there is now a growing body of evidence from brain-imaging which also supports the Orthographic Depth Hypothesis. For example, Paulesu et al. (2000) examined in two positron emission tomography (PET) studies, the reading of words and nonwords in the shallow Italian and the deep English orthography. They found that the Italian readers showed greater activation in the left superior temporal regions of the brain, which are associated with phoneme processing. In contrast, English readers showed greater activation in the left posterior inferior temporal gyrus and anterior inferior frontal gyrus, which are associated with whole-word retrieval. These results were interpreted to suggest that Italian readers rely mainly on sublexical processing at the level of letters and phonemes, whereas readers of English also rely on lexical and semantic processing to generate a phonological output (see Fiez, 2000, for an extensive discussion).

The third dimension of skilled reading, according to the strong phonological theory, involves the ability to access the lexicon or activate a word node without requiring a detailed phonological representation. The relevant predictions regarding the Orthographic Depth Hypothesis are straightforward: In shallow orthographies lexical access would be based on a relatively detailed phonological representation, whereas in deep orthographies it would be based on a relatively impoverished one. This is because the opaque relations between letters and phonemes in deep orthographies create difficulties in assembling phonological representations from print by using discrete grapheme–phoneme conversion rules. Consider, for example, the English word PINT. It is labeled *irregular* because most English words ending with INT are pronounced like MINT. However, the conversion of P-N-T into their respective phonemes does not involve any substantial ambiguity. Thus, a prelexical assembly of phonology could easily produce an underspecified phonological representation consisting of a CVCC segment such as /pent/, in which the middle vowel is not clearly defined, ranging from /e/ to /I/. The Orthographic Depth Hypothesis simply suggests that skilled readers in deep orthographies are encouraged to access their lexicon with underspecified phonological representations.

Studies in Hebrew provide strong evidence that skilled readers do not rely on a detailed phonological representation, but access the lexicon via an impoverished one. As explained above, Hebrew letters represent mainly consonants, whereas the vowel marks are mostly omitted from the printed text. In Hebrew, as in other Semitic languages, all verbs and the vast majority of nouns and adjectives are composed of roots usually formed of three

consonants. The three-consonant roots are embedded in preexisting morphophonological word patterns to form specific words. When the vowel marks are omitted from the consonant string, the same string of letters may sometimes denote up to seven or eight different words that share an identical orthographic structure but have different phonological forms. Bentin, Bargai, and Katz (1984) demonstrated that lexical decisions for phonologically ambiguous letter strings were as fast as for phonologically unequivocal words, whereas naming of ambiguous words was slower than naming of unambiguous ones. These results suggest that lexical decisions (in contrast to naming) are based on the recognition of the ambiguous consonantal cluster and do not require a detailed phonological analysis of the printed word. Similarly, Bentin and Frost (1987) showed that lexical decisions for ambiguous unpointed words are faster than lexical decisions for either of the disambiguated pointed alternatives. This outcome, again, suggests that lexical decisions in unpointed Hebrew are based on the early recognition of the consonantal structure shared by the phonological alternatives, and that finding a lexical entry does not necessarily entail the recovery of complete phonological information.

Support for these conclusions comes from recent studies using backward masking, which demonstrated that the phonological representation computed from print in Hebrew is indeed impoverished and underspecified (e.g., Frost & Yogeve, 2001; Gronau and Frost, 1997). In the backward masking paradigm (Perfetti, Bell, & Delaney, 1988), a target word is presented for a very short duration. The target word is followed (i.e., masked) by a pseudoword that appears briefly and is then replaced by a simple pattern mask. The pseudoword that masks the target can be phonemically similar to the target, graphemically similar, or an entirely dissimilar control. The subjects' task is to report in writing what they have perceived. Typically, because of the masking effect, subjects perceive only one event, the target word, and do not have any conscious recollection of the nonword mask. The short exposure characteristic of the masking paradigm allows the on-line processing of the nonword masks to merge with the incomplete processing of the word targets. Thus, in spite of the fact that the nonword masks are not consciously perceived, they exert some influence on the detection of the target.

In general, experiments using backward masking have demonstrated that nonwords which were phonemically similar to the targets they masked produced better identification rates than graphemically similar controls (e.g., Perfetti, Bell, & Delaney, 1988; Perfetti, Zhang, & Berent, 1992). This outcome suggests that the phonologic information extracted from the masks contributed to the reinstatement of the phonological properties of the targets. However, recent investigations of phonological processing in the deep Hebrew orthography showed that the probability of obtaining phonemic effects in backward masking in Hebrew depends on the phonological contrast between phonemic and graphemic masks. If the phonemic and the control masks differ by a single consonant, a phonemic effect may not be revealed (Frost & Yogeve, 2001; Gronau & Frost, 1997). This outcome was interpreted to suggest that the representations computed in brief exposures in Hebrew are indeed coarse-grained and not detailed enough to capture fine phonetic differences.

In conclusion, there is a significant body of experimental evidence which suggests that different cognitive processes are involved in skilled reading of deep and shallow orthographies. These differences concern not only the importance of prelexical phonological com-

putation relative to lexical mediation, but also the size of the computed phonological units, as well as the ability to access the lexicon with only partial phonological information.

Languages with Two Writing Systems: The Cases of Serbo-Croatian, Korean, and Japanese

Some languages have adopted two writing systems, in most cases under the influence of geographically adjacent cultures. Obviously, the introduction of yet another orthography to represent the same spoken forms introduces additional complexity. The implication of a redundant writing system therefore needs special elucidation. The present section reviews three such examples, Serbo-Croatian, Korean, and Japanese. The representational solutions in these three languages are quite different from one another, and therefore the implications for the reading process are different as well.

Serbo-Croatian

In Serbo-Croatian, both the Roman and the Cyrillic alphabets are taught to all elementary school children, and are used interchangeably by the skilled reader. Most characters in the two alphabets are unique to one alphabet or the other, but there are some characters that occur in both. Of those, some receive the same phonemic interpretation regardless of the alphabet (*common* letters), but others receive a different interpretation in each alphabet (*ambiguous* letters). Letter strings that include unique letters can be pronounced in only one alphabet. Similarly, letter strings composed exclusively of common letters can be pronounced in the same manner in both alphabets. In contrast, strings that contain only *ambiguous* and *common* letters are *phonologically bivalent*. They can be pronounced in one way by treating the characters as Roman letters, and in a distinctly different way by treating them as Cyrillic letters. For example, the letter string “POTOP” can be pronounced as /potop/ if the ambiguous character *P* is interpreted according to its Roman pronunciation. By contrast, if the letter string is taken as a Cyrillic spelling, the grapheme *P* receives the pronunciation /r/ and the string must be pronounced /rotor/ (the characters O and T are common, and have the same pronunciation in both alphabets). In the case of POTOP, both pronunciations are legal Serbo-Croatian words (the former means “flood” and the latter, “rotor”). The two alphabetic systems of Serbo-Croatian are presented in figure 15.1.

When a phonologically bivalent word of Serbo-Croatian is read in isolation, the alphabet is not specified by a context and, therefore, the spelled form can be pronounced in two different ways. Two types of such bivalent strings exist. In one of these, both pronunciations are known to the reader as words (i.e., have lexical entries). Such letter strings are both phonologically *and* lexically ambiguous. In the other type, which occurs more frequently, only one of the two pronunciations is a word, while the other is a nonword.

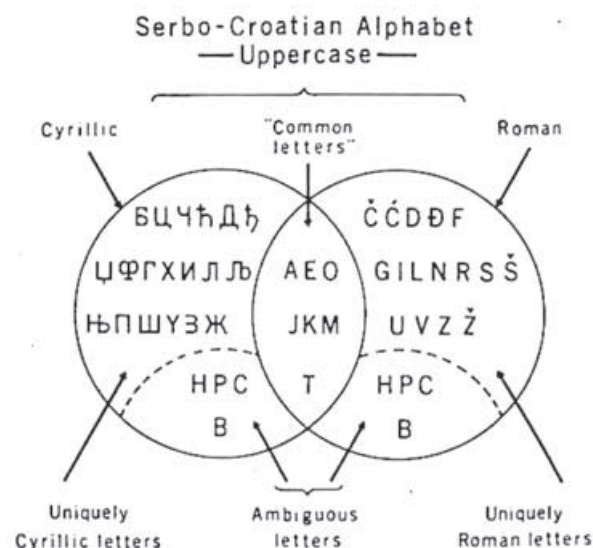


Figure 15.1 The Cyrillic and Roman alphabetic systems of Serbo-Croatian.

Such strings are phonologically ambiguous, but since they are linked to only one lexical entry they are not lexically ambiguous.

Processing implications of Serbo-Croatian orthography. Previous studies in Serbo-Croatian investigated how fluent bi-alphabetic readers process ambiguous print. Lukatela et al. (1980) studied lexical decision performance in Serbo-Croatian, comparing phonologically ambiguous and unequivocal words. They demonstrated that words that could be pronounced in two different ways were accepted more slowly as words, compared to words that could be read in only one way. Similar results were found by Feldman and Turvey (1983), who compared phonologically ambiguous and phonologically unequivocal forms of the same lexical items. This outcome was interpreted to suggest that, in contrast to English, lexical decisions in Serbo-Croatian are necessarily based on the extraction of phonology from print (Turvey, Feldman, & Lukatela, 1984).

The relative contributions of phonological and lexical factors were not directly assessed in these previous studies. Although Lukatela et al. (1980) demonstrated that phonologically ambiguous letter strings incurred longer lexical decision latencies than phonologically unequivocal strings, they did not find a significant difference in decision latencies between ambiguous strings with one or with two lexical entries. In fact, phonologically bivalent letter strings slowed participant's responses (although to a lesser extent), even if the two possible readings of the letter strings represented two nonwords (see also Lukatela, Savic, Gligorjevic, Ognjenovic, & Turvey, 1978). Interestingly, words composed exclusively of common letters that were alphabetically bivalent but *phonologically unequivocal* did not slow lexical decisions compared to their unique alphabet controls (Feldman &

Turvey, 1983). Finally, the magnitude of the difference in decision latencies for bivalent and unequivocal forms of a word varied with the number of ambiguous letters in the bivalent form of that word (Feldman, Kostic, Lukatela, & Turvey, 1983; Feldman & Turvey, 1983). In general, these results suggest that readers of Serbo-Croatian processes print by a phonologically analytic strategy, which precedes lexical access. Consequently, as a rule, their performance is hindered by phonological ambiguity (see Feldman, 1987, for a review).

In another study, Lukatela, Feldman, Turvey, Carello, and Katz (1989), investigated whether the presence of semantic context can override an ambiguous alphabetic context. They showed that the correct and consistent alphabetic assignment of a letter string can indeed be offset by previously accessed lexical entries (that are activated by semantic information). Hence, in contrast to the previous conclusions of Turvey et al. (1984), who suggested that a prelexical phonological analysis of print is mandatory in Serbo-Croatian, these results demonstrate that the Serbo-Croatian reader can also be affected by the lexical characteristics of the printed stimulus, if the experimental conditions invite deeper processing.

In another study, Frost, Feldman, and Katz (1990) presented subjects with stimuli that could be pronounced differently in the Roman or the Cyrillic alphabet. Some of these strings had two different meanings, one for each pronunciation; for others, only one of the two pronunciations was meaningful. Frost et al. (1990) used a matching task in this study; participants were presented with an ambiguous printed word and, simultaneously, with a spoken word, and were required to determine if they matched. The spoken words were either presented clearly or degraded by noise. The speed of matching the spoken words to phonologically ambiguous letter strings was measured relative to their phonologically unequivocal controls. The results indicated that phonological ambiguity slowed stimulus matching. However, phonological ambiguity had a greater effect when the phonologically ambiguous form represented two meaningful words. These results again suggest that readers of Serbo-Croatian process print in a phonologically analytic manner, as they are sensitive to the ambiguity presented by the orthographic structure deriving from both phonological forms. However, readers of Serbo-Croatian are affected not only by the number of possible pronunciations of a printed word, but also by their lexical status. Thus, it seems that lexical effects can also be demonstrated in the shallow Serbo-Croatian, demonstrating the flexibility of readers in employing prelexical as well as lexical procedures for computing phonology.

Korean

In contrast to Serbo-Croatian, which adopted two writing systems that provide different graphic signs for the same alphabet, the Korean orthography has one writing system that is alphabetic (*Hangul*) and another that is logographic (*Hanza*). In a way that is similar to English, the graphemes in Hangul represent the phonemes of spoken Korean. However, in contrast to the case of English, the representational principle in Hangul is very shallow, as graphemes represent phonemes consistently. In this context, Korean might be similar to Spanish or Italian if it did not include a second writing system that is logographic.

Because of influence from nearby China, written Korean imported a substantial number of Chinese logographs. This script, called Hanza, represents the spoken words of Korean through a logographic representation of morphemes. Thus, the printed shape of the logograph in Chinese and Korean may be the same, but its phonological reading is different. This is because the logographic symbols were meant to represent meaningful morphemes with a pronunciation differing from the original one, due to the different spoken language into which they were imported. In Korean, only 20% of printed words are written in the logographic Hanza, whereas the other 80% are written in the phonologically shallow Hangul. Also, whereas Hanza words can be printed in Hangul, the reverse is not always true and some words can be written only in Hangul. Thus, Hangul is considered to be the dominant script. The interesting aspect of printed Korean, however, is that Hanza and Hangul characters are mixed inconsistently within a given text to facilitate reading. In fact, it is not possible to find a Korean text that is printed exclusively in the logographic Hanza (see Cho & Chen, 1999, Kang & Simpson, 2001, and Simpson & Kang, 1994, for a detailed description of Korean orthography). Examples of Hangul and Hanza words are presented in table 15.3.

Processing implications of Korean orthography. Unsurprisingly, studies conducted in Korean revealed that Hangul and Hanza are processed differently by the Korean reader. As the Orthographic Depth Hypothesis predicts, phonological assembly is favored by Korean readers when the stimuli are printed in the shallow Hangul orthography, even when semantic processing was required by the task (Cho & Chen, 1999; Simpson & Kang, 1994). The question of interest in the case of Korean concerns, however, the *acquired flexibility* of readers to engage in entirely different modes of processing when the text includes both a shallow phonographic script and a pure logographic one. This flexibility was examined in a series of experiments by Simpson and Kang (1994). They found that when Hangul words were presented alone, there was a greatly reduced frequency effect in naming, suggesting that Hangul script is indeed processed through sublexical analytic computation. In contrast, when Hanza dominated the stimulus list, greater frequency

Table 15.3 Korean Words Printed in the Alphabetic Hangul and the Logographic Hanza

<i>Hangul</i>	<i>Hanza</i>	<i>Pronunciation</i>	<i>Translation</i>
남/남자	男	nam/nam-dza	a man, a male
인간	人間	in-gan	a human being, a man, a mortal
친고	親舊	tchin-go	a friend
항목	項目	hang-mok	a head, an item
우유	牛乳	u-yu	cow's milk
맥주	麥酒	mek-tsu	beer, ale

effects were found in reading the same Hangul words, demonstrating greater lexical involvement in reading. Thus, it seems that Korean readers can control the extent of sublexical versus lexical computation as a function of list composition.

In a more recent study, Kang and Simpson (2001) monitored naming latencies of words printed in Hangul or Hanza, keeping track of the order of word presentation. The results showed that a single Hanza word was sufficient to initiate the lexical processing of a subsequent Hangul target. In contrast, two preceding Hangul words were required to initiate the sublexical processing of a Hangul target. This asymmetry derives from the fact that Hangul words can be named either lexically or sublexically, but Hanza words can be named only following access to the visual-input lexicon. But note that even though Hangul words can be named using the same routine as Hanza words, subjects always seem to revert to prelexical computation following the presentation of a few Hangul words, in spite of the ongoing appearance of Hanza words in the stimulus list. This outcome coincides well with the assumption that prelexical computation is the default procedure in shallow orthographies (Frost, 1998).

In yet another experiment Kang and Simpson presented subjects with Hangul and Hanza words preceded by a cue indicating which script would be seen next. Frequency effects in naming Hangul words were not found if readers were informed by the cue about the upcoming Hangul script, whereas frequency effects were clearly present when subjects were not cued. These results again suggest that subjects employ sublexical phonological computation for naming Hangul by default. Thus, the results from Korean point to two main conclusions. First, skilled readers of languages with two scripts adopt a strategic flexibility in using lexical versus sublexical routines. Second, the default routine for shallow orthographies involves mainly prelexical computation even for skilled readers.

Japanese

In several ways, the Japanese and Korean writing systems are similar because both were influenced by the writing system of mainland China. Thus, modern Japanese is written with a logographic script imported from China called *Kanji*, along with a phonographic system called *Kana*, which comprises two syllabaries, named *Hiragana* and *Katakana*.

Kanji are logographs representing morphemic units. Many Kanji words have two pronunciations: a Kun-reading consisting of the Japanese spoken word that conveys the meaning of the Chinese logograph, and an On-reading, which is essentially the original Chinese spoken word that was introduced and incorporated into the Japanese vocabulary. However, since Chinese is a tonal language and Japanese is not, the original Chinese pronunciation was distorted, and the On-reading does not match exactly the Chinese phonetic structure. Quite a few Kanji words have more than one On-reading reflecting different periods of borrowing from Chinese. Moreover, sometimes a given logograph stands for several morphemes with different meanings and pronunciations. Kanji characters are used mostly to represent lexical categories such as nouns, verb or adjective stems, as well as adverbs. The estimated number of Kanji characters employed in newspapers in Japan is approximately 3,200. The important feature of Kanji in the present context is that the characters cannot be decomposed into separable phonemic components. Their

exact pronunciation can only be determined through context, and readers need to consider the particular set of characters that combine to form the words (most On-readings are given to Kanji words having two or more characters) to know their phonemic structure.

In addition to Kanji, Japanese has two sets of phonographic characters representing the permissible syllables in the languages: Hiragana and Katakana. The present forms of Hiragana and Katakana were fixed by the Ministry of Education of Japan in 1900. There are 46 basic hiragana syllables, to which 25 variations are added. In addition, 20 hiragana characters can be modified with diacritic marks to change their pronunciation. Hiragana is used mainly to represent the grammatical elements of a sentence, such as auxiliary verbs, particles, and inflectional affixes of nouns. It is also used to represent native Japanese words for which there are no Kanji characters. Katakana is used to write foreign names, loan-words, scientific terms, and the like. Table 15.4 presents syllabic characters in Hiragana and Katakana as well as a few examples of Kanji words.

In general, all words in Japanese can be written in Kana. Thus, it seems that there is no apparent need for Japanese to use the logographic Kanji system. However, since Japanese contains a large number of homophones, semantic disambiguation is often based on the usage of Kanji characters. Also, since Japanese is written without spaces between words, the incorporation of Kanji in the text provides important cues regarding morphological segmentation. Thus, texts printed entirely in Kana are atypical.

Table 15.4 Examples of Syllabic Characters Printed in Hiragana and Katakana and Examples of Words Printed in Kanji

<i>Hiragana</i>					<i>Katakana</i>				
あ	い	う	え	お	ア	イ	ウ	エ	オ
a	i	u	e	o	a	i	u	e	o
か	き	く	け	こ	カ	キ	ク	ケ	コ
ka	ki	ku	ke	ko	ka	ki	ku	ke	ko
さ	し	す	せ	そ	サ	シ	ス	セ	ソ
sa	shi	su	se	so	sa	shi	su	se	so
た	ち	つ	て	と	タ	チ	ツ	テ	ト
ta	chi	tsu	te	to	ta	chi	tsu	te	to
<i>Kanji</i>	<i>Pronunciation</i>		<i>Meaning</i>		<i>Meaning of Each of the Characters</i>				
日本	Nihon or Nippon		Japan		sun/origin				
日本人	Nihonjin		Japanese (people)		sun/origin/people				
自然	shizen		nature		self/natural				
和	wa		harmony		harmony				

Processing implications of Japanese Orthography. Some early research in Japanese employed the two writing systems of that language for the purpose of examining the relative superiority of visual versus phonological processing during printed word recognition. For example, Feldman and Turvey (1980) contrasted naming latencies for the same words printed in Kanji and Kana. They demonstrated that words that are usually printed in the Japanese deep logographic Kanji (e.g., color names) were named faster when printed in the shallower syllabic Kana than in their familiar Kanji form. These results were interpreted to suggest that naming in an orthography that lends itself to phonological assembly is necessarily faster than in a deep orthography that promotes visual encoding and visual access. Besner and Hildebrandt (1987), however, argued that familiarity does play a significant role in reading Japanese Kana. They showed that words regularly printed in Kana were named faster than Kanji words printed in Kana. Similar results were reported by Buchanan and Besner (1993).

There is ample evidence that the reading of Kana words involves phonological encoding. For example, Taft and Tamaoka (1994) found using the lexical decision task that the rejection of pseudohomophones printed in Katakana is affected by phonological similarity or dissimilarity to real words, at the level of single phonemes rather than full syllables. These results suggest that Japanese readers are sensitive to phonemic units when processing Kana and the smallest unit of phonological processing in Japanese is not necessarily syllabic.

The interesting question, however, concerns phonological processing during reading of Kanji. Obviously, since Kanji characters do not lend themselves to phonemic decomposition, it has been suggested that their meaning is accessed directly from the print (e.g., Shimamura, 1987). However, more recent studies using the semantic categorization task (e.g., Wydell, Butterworth, & Patterson, 1995; Wydell, Patterson, & Humphreys, 1993) have shown that the reading of Kanji characters involves access to semantics from both the orthographic input lexicon and the phonological output lexicon. Thus, it seems that phonology mediates access to meaning in reading Kanji just as it does with Kana. The suggestion that the reading of Kanji words involves direct access to phonology without semantic mediation is also supported by neurological studies. For example, Sasanuma, Sakuma, and Kitano (1992) presented several case studies of patients with severely impaired comprehension, who could nevertheless read aloud Kanji words without great difficulty. Such patterns of reading disorders suggest that the reading of Kanji characters may be independent of the retrieval of meaning.

Another study by Wydell and her colleagues (Wydell et al., 1995) investigated the grain-size of the computed phonological units of Kanji words, by monitoring print-to-sound consistency effects of characters in naming. Consistency was defined in terms of pronunciation ambiguity, reflecting whether or not the constituent Kanji characters had an alternative On-reading or Kun-reading. Clear effects of character frequency and familiarity on naming were found, but there were no effects of consistency. These results were interpreted to suggest that the phonology of Kanji words is computed at the word level rather than the character level. This conclusion coincides well with the Orthographic Depth Hypothesis prediction that readers of deep orthographies use larger-sized units than readers of shallow orthographies, while generating a phonological representation from print.

Summary and Conclusions

This chapter has discussed how skilled word recognition processes differ in different orthographic systems. In general, different models of skilled reading outline different architectures of the mental lexicon, and define different dynamic processes that operate upon these architectures. The description of what skilled reading entails is, therefore, necessarily model dependent. This chapter has focused on two main theories of visual word recognition: the dual-route theory and the strong phonological theory. From an architectural perspective, both theories postulate a nonlexical route that operates using grapheme–phoneme conversion which connects to a phonological output lexicon, and both theories recognize that an orthographic lexicon is a necessary component of a lexical system. However, in dual-route theory, skilled reading is described by an increased reliance on the orthographic input lexicon, which activates directly the phonological output lexicon as well as the semantic system. In contrast, strong phonological models regard the prelexical computation of phonology as the main engine driving the processing of printed information. Hence, the theory considers the product of this computation to be the core output of the cognitive system. Lexical influence is perceived as a subsequent top-down shaping of the prelexical product, which provides a complete and phonologically detailed representation. Given these assumptions, skilled reading in strong phonological models is seen as a convergence of three abilities: the ability to compute a phonological representation with ease using sublexical units, the ability to use larger-sized sublexical units during the computation process, and the ability to access the lexicon with relatively impoverished phonological representations.

Keeping our description of skilled reading in mind, this chapter has focused on how the linguistic environment of the native speaker shapes the structure of lexical knowledge. The phonological and morphological structure of different languages has historically determined the kind of orthography they adopted. The variety that exists in spoken languages has given rise to a variety of orthographies, reflecting a range of relationships to different languages' structural characteristics. Since orthographies differ in the relations between the spelling and phonology, as well as the size of the phonological unit transcribed by their graphemes, the cognitive processes involved in skilled reading are orthography dependent to some degree.

We have considered a variety of orthographic systems, including English, Hebrew, Serbo-Croatian, German, Korean, and Japanese. The research reviewed supports several conclusions. First, readers always display a fine-tuning to the characteristics of the presented text. Thus, if orthographies are deep or shallow, if they are phonographic or logographic, they impose different cognitive processing routines on the reader. This form of flexibility or strategic control is characteristic of our lexical processing system. Another conclusion concerns the default procedures employed during reading. The evidence described in this chapter suggests that if fast and relatively accurate sublexical computation is supported by the orthographic system, then it becomes the default procedure even for skilled readers. In this respect, deep and shallow orthographies display a clear asymmetry. Whereas lexical processing by fast access to the visual input lexicon is a viable routine in any writing system (phonographic or logographic, deep or shallow), sublexi-

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cal computation requires transparent relationships between spelling and phonology. The bias for sublexical computation in shallow orthographies portrays an interesting constraint on theories of skilled reading. It suggests that the conversion of sublexical units into phonological units is not a strategy adopted only by beginning readers. Rather, it is a default operation in the reading process.¹

Note

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