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# FROM PRINT TO SOUND

PHILIP A. LUELSDORFF

*University of Regensburg*

## 1. *Current controversies*

Patterson, Coltheart & Marshall (1985:xxi), in a stimulating collection of neuropsychological and cognitive studies of phonological reading, suggest the "minimal" model of reading aloud and reading for meaning reproduced in Fig. 1. Here, the boxes represent processing components and the arrows

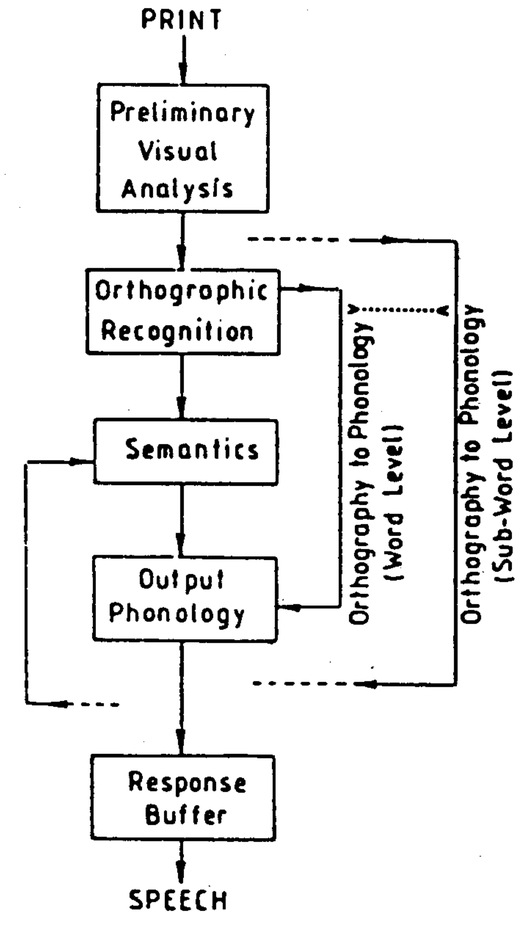


Fig. 1: A minimal nadel of reading aloud and reading for meaning

the information flow between them. The arrows with spaced lines as shafts stand for interconnections whose status in respect of information transmitted and loci of arrival and departure is disputed.

The central controversy concerns the status of the subword procedure as either non-lexical or lexical. According to the authors, if the subword procedure is non-lexical, then orthographic segmentation follows preliminary visual analysis of the letter string; if lexical, then the orthographic segmentation necessary for subword translation occurs in the orthographic lexicon.

A second controversy, represented by >...< in the figure, relates to the nature and size of the units involved in translation from orthography to phonology, whether they are entire written words, or graphemes, or something intermediary between whole words and graphemes. Clearly, this second issue is not independent of the first, and vice versa. The output of segmentation must meet the input demands of translation, and the input demands of translation constrain the form of segmentation.

A third moot point, we might add, is the nature and locus of self-correction mechanisms for reading (Temple 1985:273) and spelling (Luelsdorff 1986). Temple proposes "lexical checks" in the form of mechanisms for reparsing the incorrectly parsed output of visual analysis and for retranslating erroneously applied mappings between graphemes and grapheme chunks, on the one hand, and phoneme or phoneme strings, on the other, resulting from the perceived mismatch between the output of translation and the phonology of the word in question. In Luelsdorff (1986), we attribute errors in language and errors in action to the wrong application of strategies and the application of the wrong strategies, triggering the error mechanism of substitution, omission, addition, and displacement – reduceable to mechanisms of omission and addition – and correction to the reversal of these error mechanisms resulting from the application of strategies that are normative. Moreover, the error mode and correction mode, qua mechanisms, where help to apply at all levels of linguistic representation – not just the orthographic – resulting in a more isotropic and less modular view of language. More recently (Luelsdorff & Eyland 1988), we show that orthographic errors cannot be corrected without simultaneous access to phonology, morphology and semantics – correcting ⟨weat⟩ to ⟨wait⟩ depends on knowing that ⟨wait⟩ is intended, and not ⟨wheat⟩, i.e. phonology; correcting ⟨dogs⟩ to ⟨dog's⟩ requires access to morphology; and correcting ⟨grate⟩ to ⟨great⟩ demands knowledge of semantics – also pointing in the direction of a conception that is essentially less modular and more interactive, which, in turn, suggests a notion of language as a system defined by its internal and external constraints.

In the following we present the outline of an alternative model of oral reading which attempts to resolve these three controversies.



## 1. *Lexical vs. sublexical subword reading*

Henderson (1985:465) lists the three original reasons for posting a non-lexical pathway to oral reading: (1) to provide a mechanism for translating into speech printed forms that have not previously been encountered; (2) to explain why words that are "regular" in their spelling-sound correspondences are sometimes handled faster in oral reading; (3) to explain the reading errors that characterize surface dyslexia. In our view these three facts are explained by a theory of oral reading which is exclusively lexical, thereby questioning the existence of the non-lexical route to oral reading. In support of this position, we observe that:

### *The ontolological status of phonemes and graphemes*

1.1. The ontological status of the grapheme (and the phoneme) is in-the-word. On this lexically holistic view, both graphemes and phonemes function as parts of words in order to semantically distinguish words, not individually in isolation. Isolated, decontextualized graphemes and phonemes as extralexical distinctive entities are the fictitious products of a methodology which is atomistic, rather than holistic. Minimal pairs like /šip/ *sheep* /šIp/ *ship* lead to the conclusion that /i/ in *sheep* i.e. that contrast is a lexical semantic function, not that /i/ and /I/ contrast in isolation, i.e. non-lexically. Similarly, the graphemes ⟨ea⟩ and ⟨ee⟩ lexically phonologically contrast ⟨meat⟩ with ⟨meet⟩, and ⟨ea⟩ and ⟨ee⟩ lexically phonologically contrast ⟨great⟩ and ⟨greet⟩. We must know that ⟨ea⟩ is in ⟨great⟩ to pronounce it /e/ and not /i/ as in ⟨eat⟩. From this we conclude that graphemes are *lexical* phonological and *lexical* semantic functions and that reading cannot consequently be non-lexical. In cases of regular grapheme-phoneme correspondences, whatever the interpretation of regularity, the word containing the correspondence must be known in order to determine whether a contained grapheme-phoneme correspondence is regular. /ae/ is the regular pronunciation of ⟨a⟩ in ⟨ban⟩, but not in ⟨bane⟩, and /ð/ is the regular pronunciation of ⟨th⟩ in function words, but becomes much less regular elsewhere. In a highly contextualized orthography like English, it makes little sense to regard sub-word orthography-to-phonology as non-lexical.

1.2 *Lexical regularity and lexical frequency.* Bub, Cancelliere, and Kertesz (1985:21) show that both regular and exception *words* are more prone to reading errors if they are also low frequency *words*. Now, if there is an inverse relationship between error-proneness and *word regularity* and word frequency,

the values of the variable of error-proneness are dependent upon the values of the variables of *lexical* regularity and *lexical* frequency. Consequently, the subword procedure must be regarded as *lexical,* not non-lexical.

1.3 *The word-effect for errors.* In our studies of the acquisition of L2-English orthography (Luelsdorff 1986, 1989), we have repeatedly noted that the same normative phoneme, with the same normative spelling, exhibits different sets of misspellings in different words. For example, the /ɔ/ in ⟨walk⟩ was misspelled ⟨oo, o, oa, aCCe⟩, while the /ɔ/ in ⟨called⟩ was misspelled ⟨ou, o, au, oa⟩. Moreover, the same sound with the same normative spelling may be spelling-error prone in different words. For example, the /o/ in ⟨woke⟩, with the normative spelling ⟨oCa⟩, was mispelled ⟨ooC, oC, ouC, oaC, owC, a(C)C, uCC, oo, e⟩, while the /o/ in ⟨wrote⟩, with the same normative spelling ⟨oCe⟩, was misspelled ⟨ou, oa, o, oo, oe⟩. Furthermore, the same normative spellings of different sounds in different words may be spelling-error prone in different ways. For example, the ⟨ie⟩ for /i/ in ⟨piece⟩ was misspelled ⟨eaCe, iC(C)e, ie, ea, ee, eCe, eeCe, e⟩, while the ⟨ie⟩ for /ɛ/ in ⟨girlfriend⟩ was misspelled ⟨e, ee, eCe, eeCe, e⟩, while the ⟨ie⟩ for /ɛ/ in ⟨girlfriend⟩ was misspelled ⟨e, ee, i, eeCe, ae⟩. Finally, even in those cases where the set of spelling-error types for the vowel in one word is properly included in the set of spelling error types for the same vowel in a different word, the members of each set of spelling error types for each word may exhibit different absolute frequencies and these frequencies may appear in different ranks. For example, the set of misspellings of the /i/ in ⟨cheese⟩ is properly included in the set of misspellings of the /i/ in ⟨piece⟩, but whereas ⟨ee⟩ is the most frequent misspelling of the ⟨ee⟩ in ⟨cheese⟩ (19 %), it is the fifth most frequent misspelling of the /i/ in ⟨piece⟩. These observations lead us to conclude that it is not just sounds, nor just letters, nor even letter-sound correspondences, which are misspelling-prone in certain ways, but letter-sound correspondences *in individual words.* If this is so, then it is only error-proneness in reading (cf. above) that is lexical, but also error-proneness in spelling. This error-proneness in orthography, in its two main uses in reading and spelling, supports the notion of *Lexical Orthography,* and fails to support the notion of non-lexical orthography. Consequently, both sub-word level orthography-to-phonology (sub-word reading) and sub-word level phonology-to-orthography (sub-word spelling) are lexical, not non-lexical, so that the orthographic segmentation necessary for sub-word translation occurs in the orthographic lexicon (not following preliminary visual analysis of the letter string).



*The dual-word hypothesis on spelling*

Several recent models of English contain two routes to oral reading, called the *lexical* and the *non-lexical* (Coltheart 1984: 68-69). On the lexical route, a word-specific input letter pattern is matched with the same word-specific letter pattern in the mental lexicon and associated with its phonological representation. On the non-lexical route, letter patterns serve as the input to a set of grapheme-phoneme correspondences whose successive applications assemble the pronunciations of the graphemically parsed strings.

Henderson (1984: 2-4) points out that the distinction between a lexical and a non-lexical route to oral reading is based on the dichotomization of the English vocabulary into *regular* and *exception* words, where a word is regular if its pronunciation is predictable from its spelling by means of the most frequently occurring GPCs in the language. According to the dual-route hypothesis, irregular words or irregular portions of words are read orally on the lexical route, whereas pseudowords, regular words, or regular portions of words or pseudowords are read orally on the non-lexical, rule-governed route.

How, were one to apply the dual-route hypothesis to spelling, then pseudowords, regular words and sounds with regular letter correspondences would be processed non-lexically, i.e. by means of PGCs, while irregularly spelled words or sounds with exceptional letter would be processed lexically, in a manner that is word specific. While this hypohesis predicts the occurrence of spelling errors of the reregularization type, it fails to predict error of regularization, irregularization, and re-irregularization, however, because, on this hypothesis, irregular spelling patterns are *lexical,* not rule-governed, i.e. word-specific, not rule-general. The abundance of spelling errors of regularization, irregularization, and re-irregularization, however, argues strongly against the hypothesis of a dual-route to spelling and strongly in favor of the hypothesis that irregularly spelled words, like regularly spelled words, are spelled by means of rules, i.e. PGCs. On this hypohesis, the difference between spelling a regular and an irregular word is not that the former is rule-governed, and the latter lexical, but that the former is word-general, i.e. controlled by processes affecting the majority of the occurrences of the sound-type being spelled, and the latter word-specific, i.e. controlled by processes affecting the minority of the occurrences of the sound-type being spelled, with both regular and irregular spellings being rule-governed. Since this latter hypothesis – call it the "Dual Word Hypothesis" – predicts errors of regularization, irregularization, and re-irregularization, in addition, of course, to errors of reregularization, i.e. all and only the substitution error types in our investigation (Luelsdorff 1986), we consider it confirmed.

The Dual Word Hypothesis on spelling may have implications for the Dual Route Hypothesis on reading. If, for example, spelled pseudowords are orally

read irregularly, say ⟨preat⟩ as [pret], it must mean that they are being read via a nonlexical route. But if a reader is reading pseudowords via the non-lexical route, it must mean that the irregular spellings themselves are not lexical, but rule-governed.

## 2. *The orthographic component*

Prelilminary visual analysis, at best, yields a letter string, segmented into single letters, if the letters are spaced. Note that the resultant units *cannot* be graphemes, since graphemes, by definition, are letters and letter combinations whose status as graphemes derives from their *relations* to phonemes and the *conditions* placed on the realizations of those relations, whereby the phonemes and the conditions placed on grapheme-phoneme relations do not and cannot result from preliminary visual analysis.

In our view, the output of Preliminary Visual Analysis –a word-level, segmented, linearily-ordered letter-string– is *matched* (not parsed!) with the terminal string of the most similar hierarchical orthographic representation in the Orthographic Component of the mental lexicon. The result of this matching is the augmentation of the original information in the visual representation of the segmented, linear string by the additional, hierarchical information in the orthographic representation in the mental lexicon. The hierarchical information in the lexical orthographic representation is the parse which is itself a function of the orthography, phonology, and morphology interface.

If the relations between phonology and orthography were biunique, then orthography could simply inherit phonology, i.e. orthographic and phonological parsings would be identical. Violations of univocality and complexness (Sgall 1987), with attendent frequency differences in signifiers, together with phonological, morphographemic, morphological, syntactic, semantic, and pragmatic factors conspire to complicate the orthographic representation, rendering it error-prone, difficult to learn, and subject to so much controversy.

Sublexical orthography to phonology requires the use of the hierarchical information in the orthographic representation in order to translate print to sound. We envision the relation to be an ordered triple R=(G, C, P,), where R=oral reading, G=grapheme, C=condition, and P=phoneme. Alternatively, oral reading is an if – then condition, such that G is read P if C, and spelling an if – then condition, such that P is spelled G if C. By way of exemplification, consider the examples in columns I, II, and III in Fig. 2.

In column I, V2 c-commands both V1 and C2, and C2 c-commands V1. If only C2 c-commands V1, the pronunciation of V1 is /æ/. If V2 c-commands V1 and V2, the pronuncation of V1 is /e/. Following the practice in syntax, we



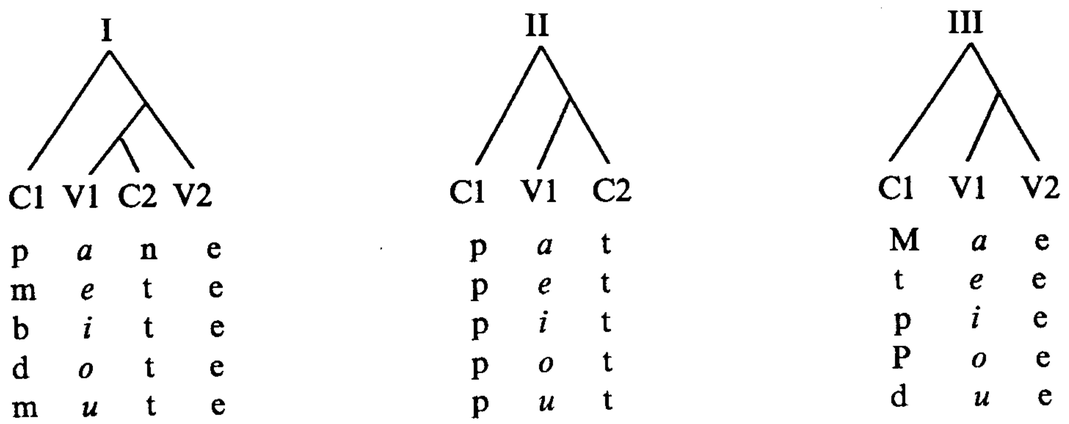


Fig. 2: Configurational Orthography

therefore say that C2 minimally governs V1, that V2 maximally governs V1, and that maximal government takes precedence over minimal if a minigoverned structure is included in one that is maxi.

In column II, C2 minigoverns V1. Since the governing node is a consonant, the nuclear vowels are pronounced short.

One by-product of this analysis is the orthography to phonology (O-P) of words of the type fund in column III. Here, V2 minigoverns V1, with the result that the vowels are pronounced long, as in column I.

In columns I and III the vowels are pronounced long (in fact, *via* letter-naming as an oral reading strategy), while the vowels in column II are short. Columns I and III differ from column II in that the vowels pronounced in the former are governed by V, while the vowels pronounced in the latter are governed by C: V-governed vowels are long, C-governed vowels are short. If we assume that the node dominating both the governor and the governed (the governing category) inherits the category label of the governor, then governed long vowels have V as their governing category, whereas governed short vowels have C. Furthermore, since it is the right-daughter that is the governing node in the examples I-III, and this node is to the right of the nucleus, we consider it also established that government in the rhyme proceeds from right-to-left. Finally, since maximal govern ment takes precedence over minimal government, we consider it demonstrated that government proceeds from the top of the tree to the bottom. On this view, government within the rhyme describes two paths from top to bottom, one to the governor, one to the governed. Once this succeeds, no additional relationship of government is of interest in respect of the node that has already been established as governed. In such a fashion, the values of the variable terminal nodes are uniquely bound.

Were the procedure bottom-to-top, the values of the variable terminal nodes would have to undergo reassignment with each differentially-valued government relationship as one proceeded up the tree.

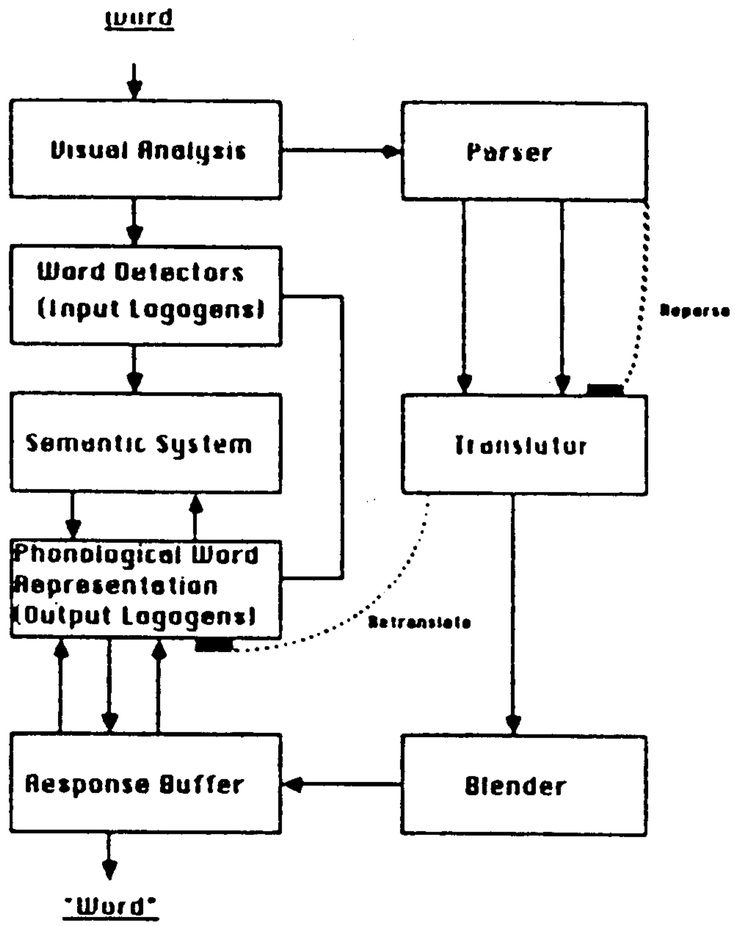


Fig. 3: An amended model of reading

Thus viewed, relations such as c-command and government are conditions on the phonology of orthography, and their contribution to the description and explanation of the orthography and phonology interface, coupled with their established explanatory value in syntax, yield a less modular and more interactive and integrated view of English.

As we saw above, one current controversy involves the size and nature of the units involved in the translation of orthography to phonology. Within the framework under development, the translation from orthography to phonology is expressable in terms of a set of if-then conditions. The then-parts of these conditions are grapheme – phoneme correspondences in the sense of Venezky (1970). The if-parts, however, are elements and relations like c-commands, governs, and binds, familiar from generative syntax. We are thus dealing with sets of ordered pairs and triples with coordinates like V, C, R=/r/, and L=/l/. These relations are *lexical* in that they are defined on subtrees of trees of orthographic representations of words. The *extent* to which they are sub-word



procedures depends upon their depth, whether they emanate from the onset, root, rhyme, nucleus, or offset, and the number of terminal elements involved.

Quite apart from the nature and size of the units involved in orthography-to-phonology translation is the question of their structural and processing complexity (Luelsdorff 1989; Sgall 1987). The pursuit of answers to this question has led to Parametric Orthography, including the following parameters: (1) Phonological: segmental, suprasegmental, syllabic; (2) Morphological: inflectional, derivational; (3) Semantics: homophones, homonyms; (4) Pragmatics; (6) Orthographics: phonemes, graphemes, frequency (lexical and textual) of words, GPCs, PGCs. The theory of linguistic complexity is certain to illuminate aspects of orthographic processing and impairment as it has orders of normal orthography acquisition (Luelsdorff 1989).

## 3. *The reading monitor*

Reproduced in Fig. 3 is Temple's (1985:273) amended model of reading, containing a differentation of the sub-lexical route (=Patterson, Marshall & Coltheart's 1985 sub-word level) into a Parser, Translator, and Blender, with feedback loops for reparsing and reblending as parts of lexical checking (=our monitoring). Along this sub-lexical route, the Parser operates on the output of visual analysis, and the Translator operates on the output of the Parser, which yields linear parsings.

As indicated above, however, the information delivered by the visual analyser is insufficient for parsing, the units of parsing are not graphemes, parsers are not linear, and, as it stands, the existence of graphemes in the Parser assumes prior access to the phonemes of the grapheme-phoneme correspondences in the Translator, since the Translator temporally follows the Parser.

In our developing conception, the linear, literal output of Visual Analysis is linked via matching with the corresponding hierarchical orthographic tree in the mental lexicon. Then, the hierarchical orthographic tree is phonologized via print-to-sound conversion subject to conditions such as c-command and government. Then, the resulting phonologized orthographic tree is matched with the hierarchical phonological representation which, when processed, yields the oral reading of the original printed word. Like the path of a rolling snowball, each matching results in the successive accretion of information not contained in the original stimulus, but needed for the goal of oral reading, for those words which can be read without access to their morphology, syntax, and semantics. Words demanding additional information before they can be orally read and understood, such as *content* (N) vs. *content* (V), *Polish* (N) vs. *Polish* (V), *wind*

(N) vs. *wind* (V), and *inside* (ADJ) vs. *inside* (ADV), must access the morphology, syntax, and semantics.

Oral word-reading thus involves accessing-via-matching hierarchical trees of greater or lesser linguistic depth – orthographic, phonological, morphological, semantic and even pragmatic (⟨souper special⟩ 'luncheon special with soup'). It is in this sense that oral reading is embedded in grammar.

We therefore propose the following model of oral reading.

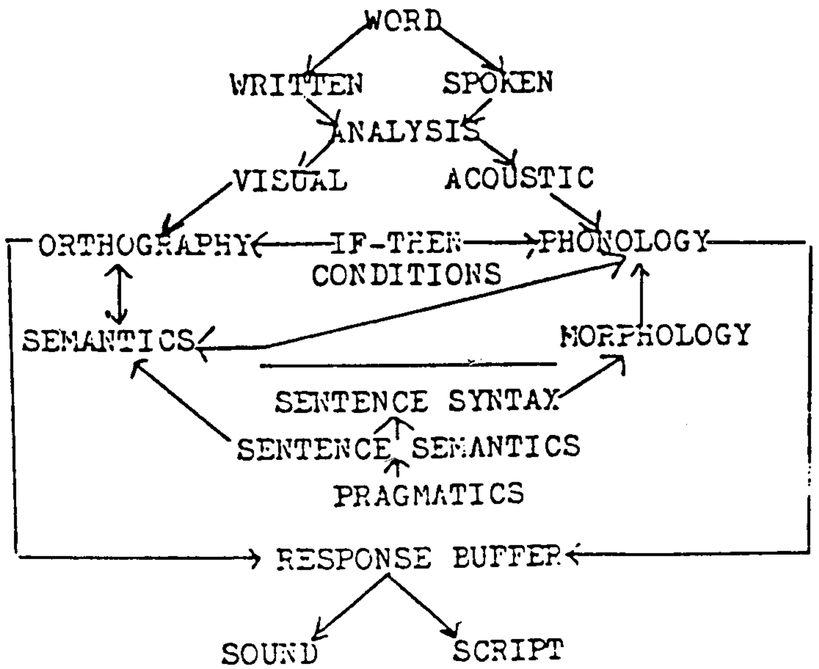


Fig. 4: Oral Reading and Spelling to Dictation

Of special interest are the conditions leading from the orthographic representation to the phonological representation (oral reading and some silent reading) and from the phonological representation to the orthographic representation (written spelling). Graphemes being signs of phonemes, our mental lexicon contains the full sets of GPCs and PGCs of English, with all the phoneme correspondences of a given grapheme and all the grapheme correspondences of a given phoneme, each entry for each grapheme and each entry for each phoneme displayed as trees with maximally balanced left and right subtrees, i.e. as a binary dictionary. Each binary dictionary, in turn, consists of subtrees for frequency, ambiguity, complexness, context, etc., which, taken together, constitute the *conditions* on using the given grapheme or phoneme in order to orally read or spell. On this view, regular and irregural correspondences are correspondences which meet different conditions. Each set of conditions



induces a unique path on the tree from orthography-to-phonology in oral reading and tree from phonology-to-orthography in spelling.

Errors, within this framework, have two basic sources: (1) violations of the if-part of the normative condition, or (2) violation of the then-part of the condition. An if-violations is a demolition or reorganization of orthographic or phonological hierarchical structure, while a then-violations is a restructuring of grapheme-phoneme or phoneme-grapheme binary dictionaries. The if-violation of assigning ⟨m⟩ in ⟨man⟩ the status of governor rather than ⟨n⟩ would result in the pronunciation of the ⟨a⟩ in ⟨man⟩ as the ⟨a⟩ in ⟨ma⟩. The if-violation of assigning the ⟨n⟩ in ⟨mane⟩ the status of governor, rather than ⟨e⟩, would result in the pronunciation of ⟨mane⟩ as ⟨man⟩. Then-violations typically involve either grapheme substitutions (visual errors) or phoneme substitutions (phonetic errors), heavily constrained in various interesting ways (Luelsdorff 1986; Treiman 1988) in first and second language development and normal and pathological use, which bear reexamination in the light of the framework proposed. For example, it may turn out to be the case that surface dyslexia is a reading disability not characterized by the inability to use the lexical route, but, rather, by the loss or impairment of the functional, hierarchical architecture of the orthographic and phonological word.

## 4. *Graphophonia*

Our model of oral reading suggests the possibility of an *oral* production based on lexical orthographic representation, which might be termed "graphophonia", in particular "lexicographophonia". Derwing & Dow (1987) indeed report rhyming and segment-counting tasks in which subjects' judgements reflect orthographic, rather than phonological structure in cases in which the two do not coincide. Furthermore, Wang & Derwing (1986), in a series of sensational experiments, show that members of derivationally related pairs, whose vowels were formerly thought to be related by the Chomsky & Halle (1968) Vowel Shift Rule, were psycholinguistically related only to the extent that the two vowels in each pair both shared the same spelling – a further remarkable demonstration of the decisive influence of orthography on phonology and, it must be said, on linguistics' seemingly phonological judgements. Such findings are easily accounted for within the proposed framework by the assumption that orthography underlies phonology in oral production, a conclusion reached years ago by the distinguished Praguian functionalist, Josef Vachek (1958, reprinted 1989). Besides spelling pronunciations and revealing psycholinguistic judgements, one is led to speculate about the role of orthography in phonology in general. Just as our conception of phonetics and phonology is called into being by our system of phonetic, phonemic, and morphophonemic transcription, it is perfectly possible

that aspects of written and oral production are underlain by orthography. In such a case, the model of oral reading might turn out to be a model of written and oral production.

On the basis of the above, the much debated Vowel Shift Rule (Chomsky & Halle 1968) would be replaced by the relevant if-then conditions on orthography-to-phonology, with ⟨s⟨ane⟩⟩, ⟨sinc⟨ere⟩⟩, ⟨div⟨ine⟩⟩, and ⟨verb⟨ose⟩⟩, for example, subject to the already existing if-then condition on lengthening in column I in section 3, and ⟨s⟨an⟩ity⟩, ⟨sinc⟨er⟩ity⟩, ⟨div⟨in⟩ity⟩, and ⟨verb⟨os⟩ity⟩ subject to the already existing if-condition on shortening in column II, where the differential hierarchical organizations in columns I and II *function* to differentiate the corresponding phonological and semantic representations, i.e. there is simply no way to distinctively read these vowel graphemes on a letter-by-letter basis and a linear representation is much more complicated than the hierarchical. On this view, the "long" and "short" vowels neither alternate nor "shift", but appear as complementarily distributed surface values of underlying graphemic variables in functionally distinct hierarchical configurations. This result, which *integrates* aspects of the orthography and phonology of derived and non-derived forms in a simple and transparent fashion, is consistent with a view of language as more *functionally interactive* than *modular*. The stress then falls on *interactive functions and dysfunctions* and the functional constraints on intramodular and intermodular interaction and dysinteraction, rather than the postulation and description of putative autonomous levels. In the final analysis, the raison d'être of levels, their very essence, is not to indulge in autonomy and self-determination, but to function to express the speaker-writer's and hearer-reader's communications and comprehension needs. Finally, the results are further consistent with the notion that the acquisition and processing of phonological representations are shaped and reshaped by the acquisition and processing of represention orthographic (Ehri 1984). Consequently, we have every reason to be sanguine about the future of investigations into the functional interaction between orthography and phonology in written and spoken language and production.

## 5. *Phonological and surface dyslexia*

Lexical, hierarchical orthography, as opposed to segmental, linear orthography sheds entirely new light on the subjects of the regularity vs. irregularity of GPCs, PGCs, and written and spoken words and, consequently, on he dual-route hypothesis on oral reading and spelling, orthography acquisition, and developmental and acquired phonological and surface dyslexia. Formerly, a GPC or PGC was considered predictable or regular if it was the most frequent in a specifiable set of *linear* grapheme or phoneme contexts, where, for GPCs,



the context could include other graphemes, word boundaries, morpheme boundaries and stress (Venezky 1970), and, for PGCs, stress and position in syllable (Hanna, Hanna and Rudorf 1968). Thus, the pronunciations of ⟨thatched⟩ and ⟨mint⟩ were considered regular, while the pronunciations of ⟨yacht⟩ and ⟨pint⟩ were considered irregular. Orally reading ⟨yacht⟩ to rhyme with ⟨thatched⟩ and ⟨pint⟩ to rhyme with ⟨mint⟩ both held to be errors of regularization, were considered indicative of an inability to access the lexical route to oral reading and consequent exclusive reliance on the non-lexical route, i.e. symptomatic of the syndrome known as surface dyslexia. On the *hierarchical* view, however, which places relations of dominance, c-command, government, bound, etc. at the disposal of the language learner-knower-user, ⟨yacht⟩ and ⟨pint⟩ are not irregural, but regular, ⟨yacht⟩ with the constituent structure ⟨⟨ya⟩⟨⟨ch⟩⟨t⟩⟩⟩ and ⟨pint⟩ with the constituent structure ⟨⟨pi⟩⟨nt⟩⟩. In ⟨yacht⟩ the ⟨a⟩ is pronounced with the long ⟨a⟩ of ⟨pa⟩ and ⟨ma⟩, and the ⟨ch⟩ is c-commanded by both an Onset (=⟨ya⟩) and an Offset (=⟨t⟩), rendering it silent like the ⟨gh⟩ in ⟨thought⟩ and analogous words. In ⟨pint⟩ the ⟨CV⟩ constituent structure is independently motivated by ⟨Si, pi, hi⟩ and ⟨⟨si⟩lent⟩, ⟨⟨bi⟩lateral⟩, ⟨⟨pi⟩lot⟩, etc., with hetorophonic homographs like ⟨⟨wi⟩⟨nd⟩⟩⟨V⟩ and⟨⟨w⟩⟨ind⟩⟩ (N) exhibiting either, depending upon the part of speech and/or meaning.

Hierarchical orthography not only makes it possible to discover and state regularities which cannot be found within the linear framework, but also does so in a more economical and revealing way. For example, the generalization that the ⟨v⟩ in ⟨CV⟩ is long if c-commanded by Onset holds not only of ⟨pint⟩, but of ⟨hi⟩ and ⟨silent⟩ and many other words as well.

A distinction has been drawn (Patterson, Marshall & Coltheart 1985:xvi) between word and sub-word levels for reading aloud, whereby the word-level procedure is not capable of producing responses for non-words and the sub-word procedure is not capable of producing correct responses for irregural words, resulting in errors of regularization. But a hierarchical word-level procedure *is* capable of producing correct pronunciations for both unambiguous and structurally ambiguous non-words. Given the visual analysis output *n+a+d*, the written word-structure rules yield ⟨⟨n⟩⟨⟨a⟩⟨d⟩⟩⟩, ⟨d⟩ minimally governs ⟨a⟩, and ⟨a⟩ is pronounced /æ/. Given the visual analysis output *s+l+i+n+t*, the written word structure rules yield ⟨⟨⟨s⟩⟨l⟩⟩⟨⟨i⟩⟨⟨n⟩⟨t⟩⟩⟩⟩, the offset ⟨nt⟩ minimally governs ⟨i⟩, and ⟨i⟩ is thus pronounced /I/. If the hierarchical analysis fails or is only partial, errors must result to the extent that hierarchical analysis is otherwise normatively needed. In the above, given just *n+a+d* and *s+l+i+n+t*, the adoption of either the auxiliary strategy of letter-naming of the auxiliary strategy of the most frequent GPCs results in pronouncing ⟨nad⟩ to rhyme with ⟨made⟩ and ⟨slint⟩ to the rhyme with

⟨pint⟩. Thus, the correct pronunciation of non-words does not necessitate the postulation of a non-lexical route to or subword level of oral reading. Rather, it requires the otherwise necessary use of orthographic word-structure rules assigning orthographic constituent structure, the resultant word-level hierarchical orthographic representations, and the appropriate lexical if-then conditions on orthography-to-phonology translation.

Finally, Lexical Orthography leads to a reassessment of the syndromes known as phonological and surface dyslexia. On the current view of phonological dyslexia, if the procedure for subword translation from orthography-to-phonology is impaired or abolished, a patient will correctly read *words* aloud by addressing their whole-word phonology, but will fail when asked to read *non-words* (Funnell 1983). Within the model of Lexical Orthography, in such cases either the if-then conditions have been abolished or dissociated from the hierarchical structure, preventing matching, or the hierarchical representations and the written word-structure rules which produce them have been abolished or damaged, also preventing matching with the if-clauses of the if-then conditions. In either case, the lexical processing of orthography-to-phonology must evidently be mediated only by memory, i.e. not regulated by if-then conditions at all. On the other hand, surface dyslexia results if the procedure for translating at the word-level is impaired, with the result that a patient will correctly read aloud and spell words with *regular* GPCs and PGCs, but make errors when reading *irregular* words (like ⟨pint⟩). Within the model of Lexical Orthography, as we have seen, many more words are *regular* than within linear representational frameworks, i.e. the frameworks on which recent neuropsychological and psycholinguistic studies of the acquired and developmental dyslexias have been based. If one assumes as a working hypothesis that all orthography to phonology processes with Lexical Orthography are regular, then the ability to orally read regular, but not irregular, taxonomic correspondences amounts to the inability to access those regular lexical orthographic hierarchical configurations which correspond to taxonomic linearizations that are irregular. In such a case, one would expect there to be something distinctive about such lexical orthographic configurations. We submit that the distinctive feature is *relative complexity*. Since the subject of orthographic complexity is many sided, one example will have to suffice. Taxononomically, ⟨pint⟩ is irregural, because the most frequent pronunciation of monographemic vowels before ⟨CC⟩ is short, not long. Consequently, pronouncing ⟨pint⟩ to rhyme with ⟨mint⟩ is producing a regularity for a normative irregularity, an error of regularization. Lexical orthographically, both ⟨mint⟩, with the short vowel, and ⟨pint⟩, with the long vowel, are regular, however, because the vowels are contained in hierarchical configurations which are mutually distinct, essentially ⟨⟨m⟩⟨int⟩⟩ and ⟨⟨pi⟩⟨nt⟩⟩, where the pronunciation of ⟨i⟩ in ⟨mint⟩ is governed by the Offset ⟨CC⟩, and the pronunciation of ⟨i⟩ in ⟨pint⟩ is governed by ⟨p⟩. The



essential difference between the two is that the ⟨i⟩ in ⟨mint⟩ is governed by its right sister-node, whereas the ⟨i⟩ in ⟨pint⟩ is governed by its right sister-node, whereas the ⟨i⟩ in ⟨pin⟩ is governed by its left sister-node. Both are cases of dominance, but the former, ⟨mint⟩, is a case of *regressive* dominance, while the latter is a case of *progressive* dominance. Now, dominance is not only prototypical of English, it is prototypical of every alphabetic orthography that is non-biunique with either earlier graphemes or later graphemes determining the pronunciation of the grapheme being pronounced. The result of this relative non-biuniqueness is that graphemes lose their status as constants and assume the status of variables bound by other graphemes in various hierarchical configurations. Of the two kinds of dominance, leftward and rightward, of regressive and progressive, the regressive is by far the most frequent. In this sense, regressive dominance is unmarked, progressive dominance marked, with progressive dominance consequently harder to come to know and much more error-prone, i.e. more complex. The fact that ⟨pint⟩ is more error-prone than ⟨mint⟩ thus falls out of the theory that ⟨p⟩ progressively dominates ⟨i⟩ in ⟨pint⟩, whereas ⟨nt⟩ regressivelly dominates ⟨i⟩ in ⟨mint⟩, and that, of the two, it is progressive dominance that is the more complex. Thus it is that taxonomic orthographic regularity and irregularity correspond to lexical orthographic simplicity and complexity, respectively. Moreover, since complexity is a collection of loci or fixations of the values of various interacting parameters, it is scaler, or gradient, rather than dichotomous, permitting far finer distinctions than those possible with the dichotomous notions regular and irregular. We therefore conclude that phonological dyslexia and surface dyslexia are each complexity disorders, the former a dissociation of the if-then conditions in the lexical entries for GPCs from the (hierarchical or not) lexical orthographic representations of words, the latter from the inability to construct a more marked (complex) hierarchical orthographic representation and/or the loss of the relatively more complex if-portions of the if-then conditions in the dictionary entries for GPCs. It appears that the predictions of the lexical orthographic complexity hypothesis on oral reading warrant testing, since the results may shed light on the similarities and differences between language knowledge and processing in acquisition, use, deterioration and loss.

## 6. *Conclusion*

Most agree that sub-word oral reading exists, but controversies have arisen over whether it is lexical or non-lexical and the nature and size of the units involved. Furthermore, the nature of self-correction in reading and spelling is far from clear. In this paper, we support the notion that the lexical route is the only route to oral reading and spelling with arguments that are philosophical,

theoretical, and empirical. Within this lexical route, we further argue, there is sub-word reading, where the dimensions of "subness" are the dimensions of the conditions on the operation of the GPCs and PGCs. These dimensions are divided into parameters with (numerical) values displayed on or-trees in binary dictionaries. The conjoining of all such trees for each grapheme and phoneme yields graphemic and-trees for oral reading and phonemic and-trees for spelling, the then-clauses of the if-then implications for reading and spelling. Parsing errors originate in departures from or the failure to acquire normative if-clauses, and abnormal then-clauses, containing the clause X spells Y, where X is a grapheme and Y is a phoneme, exhibit grapheme and phoneme deviations of a constrained variety described in the error-analytic literature (cf. Coltheart, Patterson & Marshall (1980); Luelsdorff (1986, 1989); Petterson, Marshall, Coltheart (1985).

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