READING AND LANGUAGE PROCESSING

Edited by

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1 Reading and Language Processing: Paradigms, Proposals, and Procedures

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This volume is devoted to reading and language processing, an area that has been central to the study of human cognition since the inception of modern cognitive psychology. For example, in his classic book, *Cognitive Psychology*, Neisser (1967) devoted 4 of 11 chapters to topics in reading and language. These chapters were Words as Visual Patterns, Speech Perception, Active Verbal Memory, and Sentences. In addition, most of the other chapters in Neisser's book included discussions of related topics and presented experiments in which reading and/or language played a major role.

In the 1990s, many of the topics discussed by Neisser continue to draw the attention of researchers, and new ones have been assigned high research priority. The early maturation of this field is characterized both by the evolution of new topic matter and by serious debates concerning the competing paradigms, global proposals, and methods that form the foundation of the enterprise. Our attempt to identify a representative set of contributors who are conducting research on problems that are currently cutting-edge or controversial in reading and language processing has dovetailed with our desire to highlight the latter debates. We will briefly identify these features, and link them to some of the present contributions.

Competition among *paradigms* in the study of language processes has resulted from the emergence of connectionist modeling (Rumelhart & McClelland, 1986) as a serious competitor to the antecedent symbol processing systems in cognition (Newell & Simon, 1972). The tension between these paradigms is evident in the field of language processing, but the advantages of the two approaches may also be fruitfully merged. In the present volume, for example, Just and Carpenter apply their Capacity Constrained READER model to their pupillometric data reflecting the fluctuation of effort during reading. CC READER is a hybrid model consisting of a symbolic production system and an activation-based connectionist model (see Spivey-Knowlton, Trueswell, & Tanenhaus for a purer connectionist approach). Likewise, the construction-integration model of Kintsch (1988; see Moravcsik & Kintsch, this volume) blends the symbolic construction of propositional networks with the settling, according to connectionist principles, of activation in those networks. The interplay between the two

paradigms will likely characterize research in this field in the 1990s and perhaps beyond.

These dominant paradigms form a backdrop for the evaluation of *global proposals* which, although general to the study of cognition, also take forms specific to the problems of language processing. Theorists must ask whether language processes are modular or interactionist, serial or parallel, and bottom-up or top-down; and whether or not these processes are executed to completion *immediately* upon the encoding of a spoken or written phrase. The modularity hypothesis of Fodor (1983), for example, suggests that a syntactic module might form an important basis of parsing processes. Clifton concludes that his data favor the existence of a dedicated and informationally-encapsulated syntactic module, whereas Spivey-Knowlton et al. interpret their own data to favor the free interaction of information from syntactic, semantic, and other levels of analysis.

Global proposals such as the modular versus interactionist competitors may be associated with the paradigms discussed earlier. For example, the alternative of unrestricted interaction of information is correlated with the connectionist framework, but this correlation is by no means perfect. Many connectionist models posit different cognitive systems, such as those devoted to lexical, syntactic, and semantic processing. These systems represent a degree of segregation of function, although they are not modules according to Fodor's (1983) definition. As a result, a connectionist model may exhibit elements of both of the ostensively antagonist modular and interactionist processing analyses.

Because the modern study of language processes is barely a quarter of a century old, the logic and value of relevant research *procedures* are still being worked out. This emerges as a prominent theme of this volume. In the use of eye fixations to gain insight about language processing, researchers are still considering subtle but important differences in the value of first pass, second pass, and cumulative fixations; as well as of the significance of fixations upon different text regions (current region, previous region, next region) relative to a critical word or phrase. Eye fixation measures are reported by Daneman and Reingold, Ferreira and Henderson, Henderson and Ferreira, Pollatsek, Raney, Lagasse, and Rayner, and Clifton. New implications of these data were highlighted in the two chapters by Ferreira and Henderson. Another incisive technique, the use of pupillometry to monitor on-line fluctuations of resource demands in reading, was explored by Just and Carpenter. Caveats concerning the use of the "moving window" display technique, in which successive sections of text are revealed in response to a subject's button presses, were offered by Spivey-Knowlton et al.

It would be pointless for language processing researchers to be embarrassed about controversies of method, and unwise for them not to address the controversies. The debates indicate that investigators are conscientiously scrutinizing the alternative methods that are available, and the alternate interpretations of each one.

Paradigms, theories, and methods serve, of course, to expose and organize the subject matter and content of a field. In reading and language processing, a major advance and prevailing analysis recognizes that language comprehension results

in numerous levels of representation, including the levels of surface features, lexical properties, linguistic structures, and idea networks (or textbases) underlying a message, as well as the situations to which a message refers. The interplay among these levels is emphasized in the study of Moravcsik and Kintsch. Surface features are particularly highlighted in Levy, Barnes, and Martin's study of the impact of the repetition of words and syntactic structures on reading fluency. Lexical access was scrutinized by Buchanan and Besner and by Daneman and Reingold. Linguistic and parsing processes constituted a primary focus in the investigations of Clifton, of Ferreira and Henderson, Just and Carpenter, and Spivey-Knowlton et al. The construction of a propositional textbase is addressed in the chapters of Masson and of Singer, and both of those studies also bear on the extraction of a causal situation model from the textbase. The situational level was also emphasized in Dixon, Harrison, and Taylor's study of the derivation of action plans from procedural texts.

Many other trends and issues can be discerned in the present chapters. One that promises to be of considerable importance in the near future is the growing evidence that individual differences among readers are associated with qualitative differences in their processing patterns. Reader differences in cognitive resources were examined by Just and Carpenter, and differences in readers' background knowledge were addressed by Moravcsik and Kintsch.

The present chapters may be of most direct concern to experimental psychologists, but we hope that the findings will be of interest to investigators in several of psychology's companion disciplines in cognitive science. Those chapters that inspect parsing processes may bear on linguistic theories of language structure. The computational models explicit or implicit to these investigations are pertinent to studies of natural language processing in computer science. Reading practitioners may detect important clues about basic reading processes in several of the chapters.

The collection of the chapters in this volume was undertaken in order to produce a special issue of the *Canadian Journal of Experimental Psychology*. We thank Gordon Winocur, editor of the *Journal* at the initiation of the project, for inviting us to edit the special issue. With his consultation, we invited the contributors to submit empirical reports of new research on topics central to their overall research programs in reading and language processing. We were very gratified that all of the researchers whom we invited to contribute agreed to do so. The result is 13 articles covering what we think are some of the most important and interesting areas of contemporary cognitive research.

We would like to thank the authors for giving us the honor of presenting their work. Most of the authors also served as reviewers, and we thank them for their time and effort in that regard as well. We would also like to thank Michael Anes, Tom Carr, Vic Ferreira, Albrecht Inhoff, Karen McClure, Paul van den Broek, and one anonymous reviewer for providing insightful comments on the articles. We are grateful to Colin Macleod, current editor of the *Canadian Journal of Experimental Psychology*, who provided us with guidance during the later stages

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2 Reading Aloud: Evidence for the Use of a Whole Word Nonsemantic Pathway

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Abstract It is widely assumed that the presence of an associative priming effect during the oral reading of orthographies with consistent spelling-sound correspondences signals the use of an orthographic code for lexical access (the addressed routine). Relatedly, the failure to observe such a priming effect has been taken to indicate the use of a routine that relies on subword spelling-sound correspondence knowledge (the assembled routine). This logic depends on the assumptions that (a) only the addressed routine (whole word orthographic knowledge) can produce priming, and (b) that it necessarily does so (i.e., is automatic). The present experiments show that, *taken alone*, neither the presence nor absence of priming effects in oral reading permit an inference as to whether the addressed or assembled routine is used. Converging operations which do permit such an inference are reported. The data support the view that (i) components of the word recognition system operate interactively such that use of the assembled routine yields priming under certain conditions, and (ii) normal readers of a shallow orthography use a nonsemantic, whole word pathway to name words.

Résumé Il est généralement admis que, dans le cas d'orthographes peu profondes (où il y a correspondance systématique entre la graphie et la prononciation), la présence d'un effet d'amorçage associatif durant la lecture orale marque l'utilisation d'un code orthographique pour accéder au lexique (programme adressé). Par ailleurs, on considère que l'absence d'un effet d'amorçage indique l'utilisation d'un programme qui repose sur la connaissance des correspondances entre la graphie et la prononciation à un niveau inférieur à celui du mot (programme assemblé). Cette logique dépend des hypothèses suivantes: a) seul le programme adressé (connaissance orthographique des mots complets) peut produire l'amorçage et b) il le produit nécessairement (c'est-à-dire automatiquement). Les expériences que nous avons menées montrent qu'on ne peut inférer, *uniquement* de la présence d'effets d'amorçage ou de leur absence durant la lecture orale, que le programme adressé ou bien le programme assemblé est utilisé. Les opérations convergentes qui permettent une telle inférence sont exposées dans le rapport. Les données recueillies montrent que i) les composantes du système de reconnaissance

des mots fonctionnent en interaction de sorte que l'utilisation du programme assemblé produit un effet d'amorçage dans certaines conditions et ii) les lecteurs normaux qui utilisent une orthographe peu profonde empruntent une voie d'accès non sémantique aux mots complets pour nommer les mots.

Until recently, research on visual word recognition has focussed on questions concerning how words printed in English are read. This analysis has yielded a remarkable consensus concerning some of the underlying processes (e.g., see reviews by Carr & Pollatsek, 1985; Patterson & Coltheart, 1987; see also Paap, Noel & Johansen, 1992) and has resulted in the dual route model[1]. An extension of this work to cross-orthography investigations has resulted in a large body of research. One position was articulated in the strong version of the Orthographic Depth Hypothesis, which held that the consistency of spelling-sound correspondences within an orthography dictates which of the routines of the dual route model are used during reading. Shallow orthographies (i.e., those with consistent spelling-sound correspondences) were argued to be always read aloud prelexically (e.g., Allport, 1979; Bridgeman, 1987; Hung & Tzeng, 1981; Morton & Sasanuma, 1984; Turvey, Feldman, & Lukatela, 1984). This position has since been tempered by the linguistic observation that syllabic stress can not always be derived on the basis of prelexical phonology (e.g., Katz & Frost, 1992). Consequently, some researchers assume that prelexical phonology serves to activate a phonological lexicon which then serves to mediate naming or semantic access (e.g., Carello, Lukatela & Turvey, 1988; Besner & Smith, 1992). Another solution is to assume that, additionally, a whole word orthographic routine which addresses lexical phonology is also functional in shallow orthographies (e.g., Besner, 1987; Besner & Hildebrandt, 1987; Besner & Smith, 1992; Besner, Patterson, Lee & Hildebrandt, 1993; Frost, Katz & Bentin, 1987; Katz & Feldman, 1983; Katz & Frost, 1992; Patterson, 1990; Sebastian-Galles, 1991; Seidenberg, 1985a,b).

While the strong version of the Orthographic Depth Hypothesis can thus be rejected on logical grounds, the methodology that has been used to investigate reading in various orthographies nevertheless bears on some issues which are

1 Not all theorists subscribe to this point of view. In particular, Seidenberg and McClelland (1989; 1990) argue that a single nonsemantic processing routine pronounces all kinds of letter strings be they regular, irregular, or nonwords. It suffices to say that this claim is disputed (e.g., Baluch and Besner, 1991; Besner et al., 1990; Besner, 1993; Monsell et al., 1992; Paap & Noel, 1991). See also Van Orden, Pennington and Stone (1990) and Lukatela and Turvey (1991) for the view that lexical access in English is entirely driven by subword spelling-sound correspondence knowledge. Our view is that it is one thing to produce an existence proof (e.g., a simulation) that one routine can name all kinds of words and nonwords, but quite another to show that this is what humans do.

important in their own right. Several lines of evidence relevant to how different orthographies are read are based on critical but untested assumptions regarding how associative priming effects in naming occur. The results of the present experiments, in concert with other findings, are taken to imply that there are three routines available to normal readers, at least two of which can produce a priming effect under certain conditons. We argue that, *on its own*, the presence or absence of priming effects does not identify which of several possible routines is being used. In aid of these goals we first briefly describe a three route model of word naming. We then discuss several naming experiments in the literature that examine how different orthographies are processed, and report two new experiments that illuminate which of the several available routines are used during the reading of a shallow orthography.

A Three Route Framework

Most researchers agree that reading aloud in English can be accomplished in a number of ways (e.g., see reviews by Carr & Pollatsek, 1985; Patterson & Coltheart, 1987). Figure 1 illustrates this framework.

The orthographic input lexicon contains orthographic descriptions for every word the reader knows, while the phonological input and output lexicons represent knowledge about the sounds of these words. The semantic system represents meaning, and phonemic information is represented in the phonemic buffer. Activation of entries in these lexicons and the semantic system forms the basis of reading for meaning, and reading aloud.

The assembled routine (pathway E) identifies sub-word orthographic segments and converts them into sub-word phonological segments. These segments are ultimately assembled to form a phonological code corresponding to the letter string. This procedure only produces the correct phonological code for letter strings which conform to typical spelling-sound correspondences. English has many of these regular words but it also has a number of exceptions. For example, consider the *ou* in *cougar, bough, rough*, and *ought*. Since there is no way to assign the correct pronunciation to the segment ou without word-specific knowledge, these exception words can not be read aloud correctly by a pathway which relies exclusively on subword spelling-sound knowledge.

In contrast, the addressed routine relies on whole word knowledge. A printed word first activates its representation in the orthographic lexicon. Activation then spreads through two distinct pathways. In pathway D it spreads from the orthographic input lexicon directly to the corresponding lexical entry in the phonological output lexicon. In pathways A/B the activation spreads from the orthographic input lexicon to the phonological output lexicon via the semantic system. Both of these pathways produce the correct pronunciation for all words known to the reader. Pathways A/B, D and E thus reflect three ways in which a word can be read aloud.

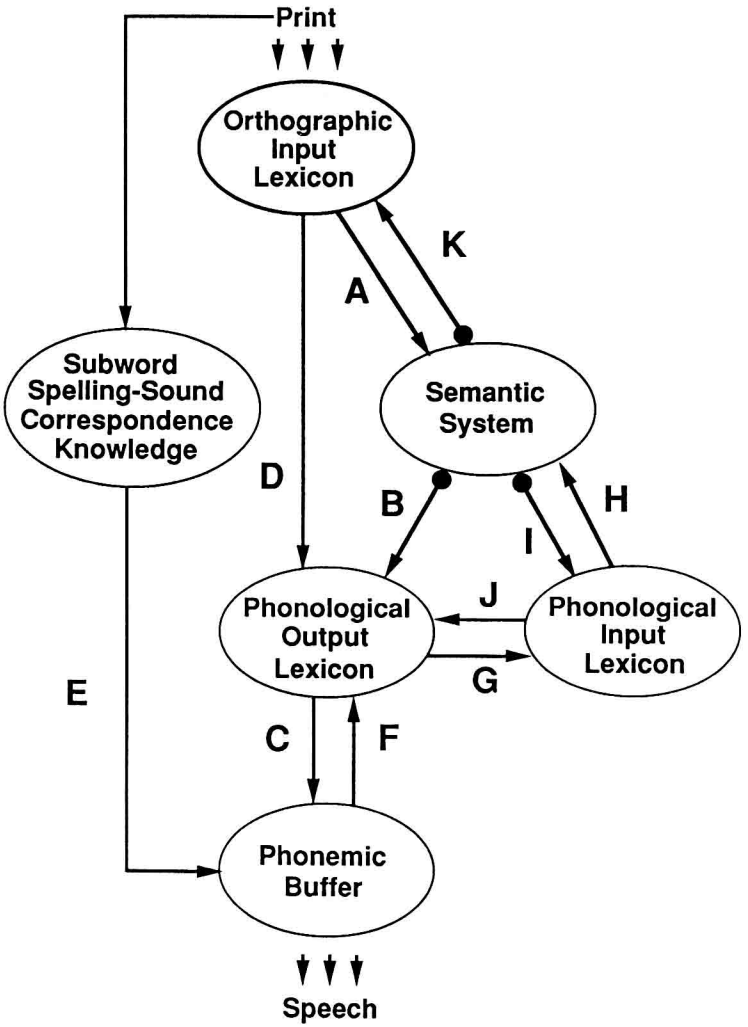

Fig. 1 A Three Route Model of Word Recognition

Evidence from Cognitive Neuropsychology

The distinction between these three pathways is supported by single case studies of patients with an acquired dyslexia who produce distinct patterns of impairment. These patterns are described in the following section.

PATHWAY E

There are a number of patients who correctly read aloud regular words such as *gave, save* and *wave* but who are poor at reading exception words like *have*. Instead, these patients often regularize exception words so that the

pronunciation of their bodies rhymes with the bodies of regular words. For example, *pint* is pronounced such that it rhymes with *hint, mint, lint*, and *dint*. This pattern of preserved reading of regular words and impaired reading of exception words is most easily understood as the expression of an intact assembled routine along with impaired access by the addressed routine to, or loss of, lexical entries in the orthographic input lexicon (e.g., Coltheart, Masterson, Byng, Prior, & Riddoch, 1983).

PATHWAYS A/B

A second group of patients' nonword reading is completely abolished, while their word reading is impaired. For example, given *tulip* they may read it aloud as *crocus*. Such semantic errors are often taken to imply that words are read via a functioning but damaged semantic system (pathways A and B). An entire book is devoted to investigations of this dyslexia (Coltheart, Patterson & Marshall, 1980).

PATHWAY D

Finally, there are other dyslexic patients who correctly read some exception words aloud but who are impaired at accessing semantic information about them. Since pathway E cannot correctly pronounce exception words, and since pathway A which accesses semantic information is impaired, the only remaining functional route is pathway D (e.g., Bub, Cancellière, & Kertesz, 1985; Schwartz, Saffran & Marin, 1980; Funnell, 1983).

These oral reading impairments are consistent with the view that the assembled and addressed routines are at least partially independent, and further, that the addressed routine can be subdivided into a semantic pathway (pathway A/B) and a whole word but nonsemantic pathway (pathway D). While this neurological evidence demonstrates that these pathways are used by impaired readers it does not force the conclusion that they are all used by intact readers. Such support comes from experiments on intact college level readers; these data distinguish between the use of the assembled and the addressed routine. In contrast, the separation of the addressed routine into two distinct pathways has received little attention in the literature on intact readers. The next section briefly describes results which support the distinction between the assembled and the addressed routine as well as the pattern of data necessary to distinguish between the use of pathways D and A.

Multiple Pathways Used by Intact Readers

Reading aloud via the assembled routine is arguably successful only when the target word follows conventional spelling-sound correspondences. Since a whole word orthographic representation of the word is not required, even pronounceable nonwords can be read aloud (e.g., *ish, lar,* and *fon*). Reading these nonwords aloud demonstrates that this routine is available to normal

readers. It does not, however, constitute evidence that this routine makes a contribution to the oral reading of familiar words. More convincing evidence comes from experiments which show that regular words (i.e., words which can be read via the assembled routine) are less affected by lexical variables such as word frequency than are exception words. Since the assembled routine operates at a sub-word level, it is by definition insensitive to whole word manipulations such as word frequency. In contrast, the addressed routine operates at the whole word level and is therefore sensitive to word frequency; this routine reads high frequency words faster than low frequency words (e.g., Forster & Chambers, 1973). Both the assembled and the addressed routines are available to read regular words, but only the addressed routine can read exception words. Since regular words typically produce a smaller frequency effect than do exception words (e.g., Paap & Noel, 1991; Seidenberg et al., 1984; Waters & Seidenberg, 1985) the interaction between regularity and word frequency implies that the assembled routine (pathway E) plays a role in reading aloud.

Do Normal Readers Use Pathway D?

The involvement of the semantic system via pathway A seems irrefutable given that we typically read words in text for meaning. We may nevertheless read exception words aloud without always first activating the semantic system, as in pathway D. No evidence yet exists for the use of this routine in intact readers of English; such evidence would be provided by a demonstration that exception words are read aloud without any benefit from a preceding related context. An analogous demonstration involving the naming of Japanese Kana is reported here.

We turn now to a consideration of priming experiments in shallow orthographies, along with a discussion of some of the critical assumptions upon which they are predicated.

Priming Effects in Naming: Standard Interpretations

Presentation of a semantically or associatively-related word prior to the target word typically yields a priming effect in a deep orthography like English (see Neely's 1991 review). It is widely assumed that the *presence* of a priming effect in *naming* reflects the use of the addressed routine, since in the dual route model pathway A directly activates the semantic system. It is also widely assumed that a *failure* to find a priming effect in naming is evidence for the use of the assembled routine. For example, in a cross orthography comparison of naming, Katz and Feldman (1983) found that English subjects showed a priming effect when reading English, a deep orthography, but Serbo-Croatian subjects did not when reading Serbo-Croatian, a shallow orthography. Frost, Katz & Bentin (1987) extended this research in a comparison of three orthographies; Hebrew, English and Serbo-Croatian. They

also report an absence of priming for Serbo-Croatian and the presence of priming for both Hebrew, another deep orthography, and English. The results of both these studies are often taken as evidence that the addressed routine was not used to name Serbo-Croatian words. In another cross orthography comparison of priming effects, Tabossi & Laghi (1992) compared the effects of priming in Italian (a shallow orthography) and English. The presence of a priming effect in both orthographies was taken as evidence that the addressed routine was used. Sabastian-Galles (1991) has reported similar findings in Spanish (another shallow orthography) and also concludes that the addressed routine is used to name words. Similar results and conclusions can be found in Seidenberg & Vidanovic (1985) and Besner & Smith (1992). It can thus be seen that the *absence* of a priming effect is standardly taken as evidence for the use of the assembled routine, while the *presence* of a priming effect is standardly taken as evidence for the use of the addressed routine.

Priming Effects in Naming: Alternative Interpretations

The presence of a priming effect in studies of shallow orthographies by Tabossi and Laghi (1992), Sebastian-Galles (1991), Seidenberg and Vidanovic (1985) and Besner and Smith (1992) do not, however, force the conclusion that the addressed routine is involved because there is no reason why the assembled routine could not also produce one (see Carello et al., 1988 for a related argument). If the semantic system operates interactively with the phonological lexicons and the phonemic buffer (i.e., pathways E,F,G,H,B and C, or E,F,G,H,I,J and C) then activation in the phonemic buffer given input from pathway E may lead to activation in the semantic system. This activation in the semantic system may be fed back to the phonemic buffer via the phonological output lexicon prior to pronunciation, thus producing a priming effect[2]. As Carello et al. (1988) suggest, in some scripts this feedback may be required as a check of the pronunciation prior to an utterance. The prior presentation of a related context may activate the semantic system and in turn the phonological output system. This would then result in a priming effect on the basis of a reduction in the time required to "check" the assembled pronunciation. It follows from this that the mere *presence* of a priming effect, *on its own*, does not distinguish between the use of the addressed and assembled routines. Similarly, the *failure* to observe priming effects during naming cannot, *on its own*, be taken as evidence for the use of the assembled routine, since pathway D (which bypasses the semantic system) might be

2 It would be more parsimonious to suppose that priming could also be produced by activation from the prime spreading from the semantic system to related entries in the phonological output lexicon prior to the appearance of the target. In this scheme, only the phonological output lexicon and the phonemic buffer need be engaged in interactive activation. However, as seen later, the data require a more elaborate account.

responsible. Indeed, while it is widely assumed that priming is "automatic" (e.g., Posner & Snyder, 1975; Neely, 1977; 1991 among others) there is evidence that even simple changes in context can eliminate priming (e.g., Friedrich et al., 1991; Smith, 1979; Smith, Besner, & Myoshi, 1992; Smith & Besner, 1992; Snow & Neely, 1987). Facilitation of target processing is not an inevitable consequence of the prior presentation of a related context.

Priming via Pathway E

Evidence that the assembled routine activates, or its output is activated by the semantic system prior to pronunciation when reading English can be found in an experiment by Rosson (1983). Rosson reported that naming a nonword like *louch* is facilitated by the prior presentation of a word like *sofa*, which is semantically related to *couch*, an orthographic and phonological neighbour of *louch*. In an extension of this approach, Lukatela & Turvey (1991) report that priming occurs when the prime is a word and the target is a pseudohomophone (e.g., *chare* was pronounced faster when it followed *table* as compared to when it followed an unrelated word). Lukatela and Turvey argue that the presence of this priming effect weakens the position of the dual route model since there is no need for a second, addressed routine if words read via the assembled routine can access lexical/semantic information.

> "In light of the evidence presented here and elsewhere for phonological mediation, we are tempted to ask whether there is experimental support for another process separate from phonological mediation". (Lukatela & Turvey, 1991, p. 960)

We believe that this conclusion is too strong, given their data. The critical data in support of this claim would involve a comparison between the priming effect for word-word pairs and word-pseudohomophone pairs. The pseudohomophones must be read by the assembled routine (since such a stimulus has no representation in an orthographic input lexicon) but, following the dual route model, words have both assembled and addressed routines available to them. Lukatela and Turvey's conclusion would be more interesting if they had demonstrated that both types of targets produced similar patterns of priming. This issue is examined in the experiments reported here.

Recapitulation

Following a review of a three route framework of oral reading in a deep orthography, we suggested that these pathways may all play a role when words printed in a shallow orthography are read aloud. Two central and widely accepted assumptions that are nevertheless problematic and require further investigation were described. These assumptions are (a) that only the addressed routine can produce priming, and (b) that when the addressed routine is employed it necessarily produces priming. Both of these assump-