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’orthographies 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. 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 conditions. 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.
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. Sebastian-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 effect². 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

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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-
tions are examined here in the context of reading Japanese Kana, because the characteristics of this shallow orthography make it possible to force subjects to read using the assembled routine.

Reading Japanese
Written Japanese consists of three distinct scripts. The logographic Kanji represents content words while the syllabic Kana scripts consist of Hiragana which represents grammatical morphemes and Katakana which represents borrowed words such as television and computer. Both Hiragana and Katakana have very consistent spelling-sound correspondences (i.e., they are shallow scripts). Transcribing a word which normally appears in one Kana script into the other Kana script produces a pseudohomophone, a word that is orthographically unfamiliar at the whole word level but retains its original pronunciation. Since readers must rely entirely on the assembled routine to read such character strings aloud, any evidence of priming for these words is evidence that the use of assembled routine can result in priming.

Determining whether the addressed routine is used (especially pathway D) is slightly more complicated. Besner and Hildebrandt (1987) and Besner, Patterson, Lee, and Hildebrandt (1993) found that orthographically familiar Kana words are named faster than Kana words which have been transcribed into an orthographically unfamiliar form. Similar results are expected in the present experiment and, following Besner and his colleagues, will also be taken as evidence that the addressed routine is used to read these familiar words. Our interest here, however, also centers on the issue of whether pathway(s) D and/or A/B are used to read such words. The use of pathway A must produce priming while the use of pathway D need not. If the orthographically familiar words in the present experiment are read faster than the orthographically unfamiliar words, yet fail to produce priming, then the use of a whole word pathway which bypasses semantics (pathway D) is implied. Experiment 1 therefore manipulates both relatedness and orthographic familiarity in the context of a naming task.

Experiment 1
METHOD
Subjects
The 12 subjects were fluent, native Japanese readers residing in the Waterloo region. Ten of the subjects were graduate students in the sciences, two were housewives. Each subject was paid ten dollars for his/her participation.

Apparatus
The stimuli were presented on a Commodore 1084 display driven by an Amiga 2000 computer. Vocal responses triggered a voice activated relay connected to a timing routine in the computer. Each trial was monitored by
the experimenter and both errors and spoiled trials were recorded.

Stimulus Materials

The stimulus set consisted of 120 prime-target word combinations. Each combination consisted of: (a) a Kanji prime (one to three characters in length) together with (b) a semantically or associatively related Katakana target word or (c) the Hiragana transcription of that Katakana word. The length of the Kana target words ranged from two to eleven characters. Twenty additional prime-target word combinations were used for the practice trials.

Procedure

Subjects were tested individually; each session lasted approximately twenty minutes and consisted of 120 trials. Each trial consisted of a presentation of a Kanji prime followed by a target printed in either Hiragana or Katakana. The targets were presented in their familiar Katakana form on half of the trials and in their orthographically unfamiliar Hiragana form on the remaining trials. Relatedness was manipulated such that on half of the trials the Kanji prime was related to the target, and unrelated on the remaining trials. The presentation order of conditions was random with the constraint that no condition be repeated on more than three successive trials. Each subject received a different random order of trials and saw each target item only once during the session. Assignment of primes to targets in the unrelated condition was also random and varied across subjects. These manipulations resulted in a subject being exposed to thirty pairs of words for each of the four conditions given by the crossing of relatedness by orthographic familiarity. The targets were rotated through each of the four conditions, thus requiring a set of four subjects to complete the design. Subjects were instructed to pronounce the target word of each pair as quickly and accurately as possible. They were told to read the prime but not to pronounce it. The timing of events was as follows: An asterisk appeared briefly in the center of the screen and was followed by a 750 ms presentation of the Kanji prime. A 250 ms ISI was followed by the onset of the target word which remained on the screen until a response was recorded. The subject then pushed a button to initiate the next trial.

RESULTS

Mean RTs and error rates for each of the four conditions are displayed in Table 1. Spoiled trials accounted for no more than one percent of the data in any condition; these are not discussed further. Error data were not formally analyzed as there were too many cells with zero as an entry. One prime-target word set was removed from the analysis because the transcription from Katakana to Hiragana was incorrect. The item analysis was therefore performed...
on the correct RT data from the remaining 119 prime-target word sets³.

Following McCann and Besner (1987), interest centers on the item analysis. In order to partial out subject variability, each subjects’ mean correct RT to all items was subtracted from their RTs for each item. The effect is similar to a regression analysis which partials out subject variability⁴. The adjusted mean RTs for correct responses to each item in each condition were then submitted to a 2 x 2 analysis of variance (relatedness x familiarity).

The main effect of Orthographic Familiarity was reliable; familiar words were named faster than the orthographically unfamiliar words, $f(1, 118) = 89.64, MSe = 354325, p < .001$. The main effect of Relatedness was marginal, $f(1, 118) = 3.67, MSe = 22314, p < .06$. The interaction between relatedness and familiarity was reliable, $f(1, 118) = 5.49, MSe = 19341, p < .05$. An analysis of the interaction confirms that the priming effect is restricted to the orthographically unfamiliar words, $t(118) = 2.51, sd = 115.07, p < .05$. The familiar words did not yield a priming effect, $t(118) = .13, sd = 77.18, p > .50$.

**Discussion**

Experiment 1 produced a highly reliable effect of orthographic familiarity with the familiar words being named faster than the unfamiliar words⁵. This replicates previous observations (Besner & Hildebrandt, 1987; Besner et al., 1993) and suggests that there are two routines available: the assembled routine for the unfamiliar words and the faster addressed routine for the familiar words.

Converging evidence comes from the interaction between relatedness and

³ Besner and Smith (1992) reported a preliminary analysis of these data in which there was one item that was subsequently removed because it was transcribed incorrectly. The means appearing in this paper are therefore slightly different from those reported in Besner and Smith.

⁴ This analysis was suggested by P. Jolicoeur.

⁵ It might be argued that the main effect of Orthographic Familiarity is due to words in Katakana being easier to name than words in Hiragana. This argument can be rejected on the basis of Besner et al.’s (1993) observation that words normally printed in Hiragana are named as fast as words normally printed in Katakana. It might also be argued that the orthographically unfamiliar words named slower in this experiment were unfamiliar at the subword level as well as being unfamiliar at the whole word level (e.g., they might have smaller summed bigram frequency counts). This argument is difficult to address directly since no published bigram frequency count exists for Kana. We note, however, that Besner et al. also report that the Orthographic Familiarity effect is length dependent. It is seen for words with four or more characters; it does not occur for shorter words in their sample. If differences in the summed bigram frequency were to offer a general account of the Orthographic Familiarity effect, they might be expected to also exert an effect on short words. A final point is that if the Orthographic Familiarity effect were simply due to differences in subword orthographic familiarity then all words would have been read by recourse to the assembled route and thus should have shown similar patterns of priming. This was not the case; orthographically familiar words showed no priming effect in Experiment 1.
familiarity. Since the unfamiliar words can only be read via the assembled routine, and only these items produced a priming effect, it must be the case that the assembled routine in this shallow orthography is influenced by semantic information prior to pronunciation. Further, since the familiar words did not produce a priming effect they must be processed by a routine that is sensitive to orthographic familiarity at the whole word level, but need not be influenced by semantic activation. The only routine that could accomplish this is the direct pathway from the orthographic input lexicon to the phonological output lexicon (pathway D). Further discussion regarding this issue follows Experiment 2.

In all previous studies with shallow orthographies, a failure to observe a priming effect in naming is associated with the presence of nonwords in the target set. In contrast, when only words appear in the target set all such experiments have yielded priming (Baluch & Besner, 1991; Besner & Smith, 1992; Seidenberg & Vidanovic, 1985; Tabossi & Laghi, 1992). The results of these experiments thus suggest that priming effects can be quite sensitive to context. Experiment 2 therefore removes the orthographically unfamiliar items in order to determine whether the familiar words would now produce a priming effect.

**Experiment 2**

**METHOD**

**Subjects**

The eight subjects were fluent, native Japanese readers. Four were visiting graduate students and four were housewives. Each subject was paid ten dollars for his/her participation. None of these subjects participated in Experiment 1.

**Materials and Procedure**

The materials and procedure were identical to that of Experiment 1 with the exception that the stimulus list contained only the 120 orthographically

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6 Though note that Carello et al. (1988) and Sebastian-Galles (1991) found a priming effect with nonwords in the stimulus set. This has been discussed by Besner and Smith (1992).
familiar Katakana target words and their Kanji primes. Each subject saw 60 related prime-target pairs and 60 unrelated prime-target pairs. The order of presentation and the assignment of primes to unrelated targets were randomized across subjects.

RESULTS
Mean RTs and error rates are displayed in the bottom half of Table 1. One item had no entries in the unrelated condition and was therefore removed from the data prior to the analysis. The analysis was therefore done on 119 items. As in Experiment 1, only correct responses were analysed. Spoiled trials accounted for no more than one percent of the observations in either condition and are not discussed further. The error data were not formally analysed, as there were too many cells with zero as an entry. Subject variability was again partialled out by subtracting the mean of each subject's correct responses to all items from their RTs for individual items. The data are clear; words preceded by a related prime were named faster than the same words preceded by an unrelated prime, \( t(118) = 4.14, sd = 53.30, p < .001 \).

Discussion
The priming effect seen in Experiment 1 results from the exclusive use of the assembled routine since only orthographically unfamiliar words (which can only be read via that routine) produce priming. Experiment 2, in which the orthographically unfamiliar words were deleted from the stimulus set, now exhibits priming for the familiar words. There are two reasons for believing that the words in Experiment 2 were read by the addressed rather than the assembled routine. First, the absolute RTs are much faster for the unrelated orthographically familiar words in Experiment 2 than for the unrelated orthographically unfamiliar words in Experiment 1. This replicates the within experiment familiarity effect observed in Experiment 1. Secondly, Besner et al. (1993) observed that character length effects are much smaller for orthographically familiar words than for orthographically unfamiliar words, as would be expected if the subword routine is dependent upon a serial assembly process. Therefore, if the words in Experiment 2 are read by the addressed routine, the length effect should be smaller than that seen for the orthographically unfamiliar words in Experiment 1, and should be similar to that observed for the orthographically familiar words in Experiment 1. The data are consistent with this argument (see Table 2). The slopes for RT as a function of word length do not differ significantly for the familiar words in Experiments 1 versus 2, \( t(116) = .41, p > .50 \). In contrast, the word length effect for the unfamiliar words in Experiment 1 is significantly larger than the word length effect for familiar words in Experiment 1, \( t(116) = 2.36, p < .05 \) and Experiment 2, \( t(116) = 2.26, p < .05 \).
TABLE 2
Length effects (ms per character) as a Function of Orthographic Familiarity for Experiments 1 and 2 Collapsed across Relatedness

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Condition</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unfamiliar Words</td>
<td>17.2</td>
</tr>
<tr>
<td>1</td>
<td>Familiar Words</td>
<td>6.7</td>
</tr>
<tr>
<td>2</td>
<td>Familiar Words</td>
<td>8.1</td>
</tr>
</tbody>
</table>

Conclusions

USE OF THE ADDRESSED ROUTINE AS INDEXED BY THE ORTHOGRAPHIC FAMILIARITY EFFECT

Only the assembled routine can be used to read the orthographically unfamiliar words. If all words were read by this routine then orthographic familiarity at the whole word level should not affect performance. Since it did, this suggests the operation of a separate routine (the addressed routine) used to read the orthographically familiar words.

UNDERSTANDING PRIMING EFFECTS

As discussed earlier, the standard assumption is that the presence of priming reflects the use of the addressed routine. However, the interaction of orthographic familiarity and relatedness observed in Experiment 1 demonstrates that this assumption is too strong. Since orthographically unfamiliar words are necessarily read via the assembled routine, the priming effect observed for these words is conclusive evidence that use of the assembled routine can result in priming. Thus, the presence of a priming effect, on its own, does not differentiate between use of the addressed routine and the assembled routine. In contrast, priming effects combined with converging operations such as word frequency (e.g., Baluch & Besner, 1991) and orthographic familiarity (as in the present experiment) do permit a conclusion as to which routine is used.

The standard explanation for a failure to find priming has been that it signals the use of the assembled routine (e.g., Frost et al., 1987; Katz & Feldman, 1983; Tabossi & Laghi, 1992). The accompanying (albeit implicit) assumption in these papers is that the addressed routine necessarily produces priming effects. The problem here is that this interpretation neglects the possibility that pathway D can be used and not produce priming. The orthographically familiar words in Experiment 1 are argued to be read by the addressed routine because they were read faster than the orthographically unfamiliar words which can only be read by the assembled routine. However, relatedness affected only the unfamiliar words. This constitutes evidence that the orthographically familiar words are read via pathway D; a lexical but nonsemantic routine. If they had been read via the semantic pathway (pathway A/B) they should have produced priming.
These data thus support a division of the addressed route into two pathways; one which is driven through semantics (A/B), and one which is not (D). To our knowledge these data are the first to support this distinction in intact readers. They therefore extend and complement the argument for three separate routines based upon data from acquired dyslexia reviewed in the introduction. This evidence for a distinction between a nonsemantic whole word routine and a subword routine is also inconsistent with the assertion that a single routine underlies the oral reading of all types of letter strings (Seidenberg & McClelland, 1989; 1990; Patterson, Seidenberg & McClelland, 1989).

INTERACTIVE PROCESSES

The interaction between orthographic familiarity and relatedness suggests that some of the components in the visual word recognition system are engaged in interactive activation (cf. McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; McClelland, 1987). The priming effect observed in Experiment 1 was limited to those words which were necessarily read via the assembled routine. If presentation of the prime served merely to activate related targets in the phonological output lexicon via the semantic system, then all words (both familiar and unfamiliar) would yield priming. Since this did not happen it is necessary to assume that while related items in the semantic system are primed, this activation does not spread automatically from the semantic system to the orthographic input lexicon and the phonological lexicons (i.e., through pathways K, B, and I). Instead, it may be released or accessed by the assembled routine via the phonemic buffer and the phonological lexicons (i.e., pathways E, F, G, H, B, C, or, E, F, G, H, I, J, C). It is assumed that while an orthographically familiar target word may activate the semantic system via the assembled routine and the phonological lexicons (i.e., pathway E,F,G, and H), directly from the orthographic input lexicon (i.e., pathway A) or from the orthographic input lexicon via the phonological lexicons (i.e., pathways D, G, AND H), previous activation in the semantic system is not released until target processing is in progress. Since pathway D results in the direct activation of a whole word representation in the phonological output lexicon, priming need not result if pathway C is fast relative to feedback from the semantic system (i.e., from pathway B or pathways I, J). The interaction between the phonemic buffer, the phonological output and input lexicons and the semantic system can be seen to yield priming for orthographically unfamiliar words because input via the assembled routine is more spread out over time. In contrast, the priming observed for the orthographically familiar words in Experiment 2 may reflect a change in organization such that spreading activation from the semantic system now feeds back to the orthographic input lexicon and/or forward to the phonological output lexicon or, alternatively, processing is based on the use of pathways
A/B rather than D. If the lexical system and the semantic system are normally engaged in interactive activation, then inhibition of pathways from the semantic system (i.e., K, B, and I as indicated in Figure 1 by the filled circles) will lead to slower naming of orthographically familiar words in the unrelated condition of Experiment 1 relative to Experiment 2. The data are consistent with this claim, as can be seen in Tables 1 and 2.

The central notion here is that inhibition plays a major role in the visual word recognition system. More specifically, activation does not appear to spread throughout the word recognition system as a matter of course. Instead, under some circumstances activation appears to spread to some subsystems, but then require additional input to spread further. The same argument has been advanced and elaborated in order to accommodate the presence/absence of word frequency effects in the oral reading of shallow orthographies as a function of the presence/absence of nonwords in the experiment (see the review by Besner & Smith, 1992). This idea can be contrasted with an interactive activation model in which activation is assumed to automatically spread between levels of representation (cf. McClelland, 1987). The present data, along with the data discussed by Besner and Smith (1992) cannot be accommodated within a framework in which activation always spreads to all levels within the visual word recognition system.

A major remaining issue concerns the need for an explanation as to why the word recognition system in shallow orthographies should appear to inhibit the spread of activation under some circumstances (e.g., Experiment 1) but, possibly, not others (Experiment 2). One speculative answer is that activation and its associated processes are resource limited and are not automatic (see also Baluch & Besner, 1991; Paap & Noel, 1991; Smith & Besner, 1993; Smith, Besner, & Myoshi, 1993). Different types of stimuli (words, nonwords) can use different processing paths; the attentional demands of these pathways may differ. Since fifty percent of the targets in Experiment 1 would not benefit from priming in the orthographic input lexicon, an inhibition of the spread of activation to that lexicon may reflect an adaptive sensitivity to context that would be most advantageous to a resource limited system.

Difficult questions remain concerning how goal setting (e.g., read this, pronounce that) and control over activation is accomplished; all the word recognition models in the literature are currently silent on this issue. These questions are among the major issues needing theoretical development if we are ever to have a comprehensive account of visual word recognition.

Summary

Contrary to the received view, (i) priming is not automatic; (ii) neither the presence nor absence of priming, on its own, is sufficient to identify the routine(s) that are being used; (iii) intact readers use a whole word nonsemantic routine to read aloud at least some of the time; (iv) the data are
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inconsistent with any model which denies a distinction between a routine which processes at the subword level and one which processes at the whole word nonsemantic level (e.g., Seidenberg & McClelland, 1989, 1990; Lukatela & Turvey, 1991, Van Orden, et al., 1990); and (v) the data are most easily understood in terms of a three route model of visual word recognition where both inhibition and activation play important roles.

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