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Naming Regular and Exception Words: Further Examination of the Effect of Phonological Dissension among Lexical Neighbours

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It is generally assumed that visual word recognition is accompanied by the activation of lexical representations corresponding to words orthographically similar to the target (neighbours). With regard to the pronunciation of their constituent units, these words can either converge with or diverge from the target pronunciation. The role of the frequency of the divergent pronunciations in print-to-sound conversion was examined in a naming experiment in which subjects pronounced regular and exception words. The results showed that naming latencies for exception words were affected by the orthographic similarity of the target with frequent phonologically divergent words (enemies). ln a similar vein, regular words which include the letters G or C (whose pronunciations are contextually determined) and which are orthographically similar to words favouring an incorrect pronunciation of the letter took longer to pronounce than regular controls. A delayed naming experiment indicated that these differences were not attributable to the articulatory characteristics of the items. Finally, it also appeared that enemy frequency influenced naming latencies but not regularisation rates and regularisation latencies. The results are discussed within the framework of current dual-route and parallel distributed processing models of reading.

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INTRODUCTION

In alphabetic writing systems, words that are orthographically similar generally sound alike. Mere observation indicates that the reader takes advantage of this principle when reading aloud. For example, when new words or pseudowords are encountered, a phonological description can be generated thanks to the statistical regularity of the mapping between orthographic and phonological units. Most current models of reading capture the reader's ability to translate both known words and pseudowords into a phonological code by incorporating two functionally distinct procedures. The first is based on memory retrieval of the phonological descriptions that have been associated with the whole orthographic representation of the word during reading acquisition. Besides this lexical look-up procedure, phonological coding in alphabetic writing systems can also operate by means of analytical correspondences between orthographic and phonological units. It was initially assumed that the two procedures behave independently (Coltheart, 1978; Paap, McDonald, Schvaneveldt, & Noel, 1987; Patterson & Morton, 1985). However, there is now some evidence to suggest that lexical and analytical knowledge combine during phonological translation of the letter string (e.g. Peereman, 1991; Rosson, 1983). The aim of the present study was to examine the hypothesis that efficiency of phonological computation depends upon the agreement between the phonological codes that the letter string activates in the mental lexicon.

Several models are explicit about the way the lexical and the analytical information is merged during phonological coding. For example, in Shallice and McCarthy's (1985) theory, phonological conversion operates in an interactive fashion at different levels of orthographic segmentation (from grapheme to morpheme). Phonological codes that are compatible between levels are reinforced (e.g. for the word ROOT, the common pronunciation /u/ of the grapheme -OO- is compatible with the common pronunciation /ut/ of the unit -OOT), whereas incompatible representations are inhibited (e.g. for the word BOOK, the pronunciation /u/ of the grapheme -OO- is incompatible with the common pronunciation /Qk/ of the unit -OOK). Lexical knowledge (the morphemic level) and analytical knowledge of print-to-sound correspondences are thus combined in building a phonological description of the letter string. More recently, Coltheart, Curtis, Atkins and Haller (1993) developed a model in which the phonological code is derived on the grounds of both lexical instances and analytical knowledge. When a letter string (word or pseudoword) is presented, it is parsed in graphemes to which the most frequent corresponding phonemes are associated. The letter string also leads to the lexical activation of the phonological counterparts of the words that are orthographically similar. The lexical and the analytical information is finally pooled in a common phonological buffer .

The assumption that phonological coding of a letter string relies on the knowledge of how orthographically similar words are pronounced is directly embodied in the parallel distributed processing (PDP) model propounded by Seidenberg and McClelland (1989). Contrary to the dual-route theory, the functional distinction between lexical and analytical processes is no longer meaningful. In the implemented network, the orthographic and the phonological descriptions of words are not locally represented, but they correspond to patterns of activation over sets of orthographic and phonological units. The strengths of the connections between orthographic and phonological units (through an intermediate layer of hidden units) are established during a learning phase and are a function of the statistical regularity of the words used in the training corpus. Therefore, phonological computation of a particular letter string is contingent upon the graphophonological characteristics of all words encountered during learning.

If lexical knowledge participates in print-to-sound conversion, then the phonological characteristics of words that are orthographically similar to the letter string should be relevant in determining naming performance. Usually, these words are referred to as *neighbours.* In several studies, they have been operationally defined as corresponding to any word of similar length that can be generated by replacing only one letter while preserving letter position (the *N* metric of Coltheart, Davelaar, Jonasson, & Besner, 1977; e.g. SAVE, SOME and NAME are neighbours of the word SAME). It has been shown repeatedly that words and pseudowords are pronounced more quickly when they have numerous neighbours than when they have few neighbours (Andrews, 1989; 1992; Laxon, Masterson, Pool, & Keating, 1992; McCann & Besner, 1987; Peereman & Content, 1995). Naming performance should also be related to the degree of phonological congruity between the neighbours and the target. While phonologically similar neighbours (e.g. BEAM, SEAM) facilitate naming, interference effects are expected when incompatible phonological codes are activated (e.g. COUCH, TOUCH). Thus, neighbourhood effects on naming performance should be a function of the relative number and/or frequencies of phonologically similar and dissimilar neighbours.

The influence of phonological similarity/dissimilarity between neighbouring words has also been explored with a different notion of neighbourhood. Words were defined as neighbours when they shared all the same letters with the exception of the initial consonants or consonant clusters. The common unit, the *word body* (Patterson & Morton, 1985), corresponds to the rime of monosyllabic words. Neighbours are categorised as *friends* when the pronunciation of the body is similar (e.g.

NAME-SAME, DOOM-BLOOM), and as *enemies* when the body pronunciations differ (e.g. NEAT-GREAT, WAVE-HAVE). Words that have friends alone are labelled *consistent*, whereas words that have both friends and enemies are labelled *inconsistent.* Inconsistent words can be further classified as *regular* when the pronunciation of the body is that which occurs the most frequently, and as *irregular* when the body receives a less frequent pronunciation. Typically, regular-body words have more friends than enemies, and irregular-body words have more enemies than friends.

Using the body-neighbour definition, Glushko (1979) reported longer naming latencies for inconsistent words and pseudowords than for consistent ones. This observation has often been considered to force the dual-route theory to abandon the hypothesis of two independent lexical and analytical processes (e.g. Humphreys & Evett, 1985; but see Patterson & Morton, 1985). Indeed, as long as phonological coding by means of grapheme-to-phoneme correspondences was assumed to be isolated from any lexical knowledge, only regularity at the level of the grapheme was expected to affect naming. In fact, words including an irregularly pronounced grapheme have been shown to lead to longer naming latencies and more numerous errors (e.g. Baron & Strawson, 1976; Stanovich & Bauer, 1978). However, Glushko's observation was difficult to conciliate within this framework given that performance for regular words was affected by their orthographic similarity (in terms of body) with irregular words. More recently, the consistency effect was successfully simulated in both the revised dual-route model proposed by Coltheart et al. (1993) and in the parallel distributed network described by Seidenberg and McClelland (1989). Moreover, as for human performance, consistency had a larger effect for low-frequency words than for high-frequency words in these simulations.

Until recently, little attention had been paid to the effect of the relative numbers or frequencies of friends and enemies. This situation is particularly striking given that most current models of reading lead to the prediction of an effect of the degree of consistency on naming performance. At first sight, Glushko's (1979) findings may suggest that the ratio of friends and enemies is irrelevant in determining naming latencies. Inconsistent words with more enemies than friends (exception words in terms of body type) were pronounced as quickly as inconsistent words with more friends than enemies (regular words in terms of body type). A similar pattern of results was reported by Andrews (1982), who observed that exception words were no more penalised for inconsistency than were regular ones. Kay and Bishop (1987, experiment 1) also obtained no significant disadvantage for inconsistent words with more enemies than friends in comparison to inconsistent words with more friends than enemies. As such, these results seem to imply that the existence of alternative phonological codes causes interference independently of the relative numbers of friends and enemies. A different explanation based on the notion of facilitation was proposed by Brown (1987). According to Brown, activation of inconsistent phonology does not cause interference, but rather consistent phonology facilitates naming. Consistent words are supposed to be pronounced more quickly because they generally have more friends than inconsistent words, and their body-rime correspondence is consequently of higher frequency. In agreement with this proposal, Brown observed similar performance for inconsistent exception words and hermits (words without friends or enemies; e.g. SOAP) that were matched in frequency of their body-rime correspondence.

In contrast, some studies suggest that numbers and/or frequencies of friends and enemies play a role in naming performance. Nevertheless, the results do not seem entirely consistent. Seidenberg, Waters, Barnes and Tanenhaus (1984) observed that while body-exception inconsistent words were pronounced more slowly than regular inconsistents, the latter were not affected by the existence of a frequent irregular neighbour. In a *post-hoc* analysis, Taraban and McClelland (1987) found a trend towards longer latencies and more frequent errors for body-exception words with numerous regular enemies than for exception words with few enemies. In a similar vein, Laxon, Masterson and Coltheart (1991) found that with primary school children, inconsistent words with few enemies were pronounced more correctly than inconsistent words with many enemies. However, while the results reported by Coltheart and Leahy (1992) suggest that this latter difference disappears for children in the third grade, Kay and Bishop (1987, experiment 2) observed in adult subjects a detrimental effect of inconsistency limited to the words with few friends.

The role of neighbourhood characteristics in skilled readers has been examined more extensively by Jared, McRae and Seidenberg (1990). The two main variables of interest were the *number* of friends and enemies and the *frequency* of friends and enemies, measured as corresponding to the summed frequencies of all friends and the summed frequencies of all enemies. Their results indicated that when matched on summed frequencies of friends and enemies, inconsistent words having more friends than enemies showed consistency effects similar to those for words having fewer friends than enemies. The relative *number* of friends and enemies had no influence on the emergence of the consistency effect, but inconsistent words were slower when enemies were both more frequent *and* more numerous than friends. These data led Jared et al. (1990, p.701) to conclude that, ". ..the size of the inconsistency effect for words is predicted by the relative frequencies of friends and enemies rather than the relative number of friends and enemies".

Although Jared and co-workers' (1990) results indicated that words with a higher summed frequency of enemies than friends (irregular words in terms of body-rime frequency) were pronounced slower than words with a lower summed frequency of enemies than friends (regular words), they did not indicate clearly whether variations in the degree of irregularity cause variations in naming performance. Indeed, in their experiment 2, inconsistent words produced significantly longer latencies than consistent controls only when the enemies were more frequent than the friends; that is, when the words were irregular in terms of body pronunciation. The two sets of inconsistent words whose friends were more frequent than enemies showed non-significant disadvantages relative to their consistent controls. In short, longer latencies were found for inconsistent irregular words but not for inconsistent regular words. Furthermore, increasing the relative frequencies of friends and enemies for regular inconsistent words produced a negligible effect of 7 msec. In fact, the role of friend and enemy frequency for exception words was only suggested by a larger effect for exception words with low-frequency friends than for exceptions with high-frequency friends (42 and 23 msec, respectively). Unfortunately, this difference was not analysed statistically.

The present experiment further analyses the role of the relative frequencies of friends and enemies in naming exception words. Three categories of uncommon exception words matched on friend frequency were used. The first two categories differed in terms of enemy frequency. In the third category, exception words had no regular neighbour (enemy). High-frequency exception words with frequent enemies were also included in the stimulus lists. Regular words were used together with the irregular words to allow for measurement of the regularity effect. If the strength of lexical influence during phonological computation depends on the frequency of the activated neighbours, then the regularity effect should be larger for irregular words with frequent regular neighbours than for irregular words with rare or no enemies. The present experiment also provides the opportunity to elucidate the locus of the consistency effect. Indeed, as introduced above, the consistency effect has generally been accounted for within the framework of models in which lexical knowledge and analytical knowledge combine during print-to-sound mapping. However, a different explanation was introduced by Patterson and Morton (1985) within the context of dual-route models that incorporate the hypothesis of full independence between the lexical and the analytical procedures. Since these models do not allow for a pooling of the lexical and the analytical knowledge into a common phonological code, the consistency effect was assumed to originate during the analytical process. Inconsistent words and pseudowords were assumed to be pronounced more slowly because they include orthographic units (the bodies) to which more than one phonological code can be attached. Moreover, the strength of the conflict between the phonological codes is proportional to their relative frequencies of occurrence in the language. In the present study, the unfamiliar irregular words with frequent enemies and the unfamiliar irregular words with rare enemies did not differ in terms of frequency of the irregular *analytical* unit (estimated by the relative frequencies of the regular and the irregular pronunciation of the critical unit in French words). Thus, any difference in the regularity observed between these two categories of words should be attributed to lexical contribution rather than to the frequency of graphophonological rules.

A second aim of the experiment was to investigate whether activation of inconsistent phonology also delays naming latencies in the case of neighbouring words whose correct pronunciations depend upon perfectly defined contextual rules. This was explored by using a last category of words which included the letters G or C. In French, the pronunciations of these letters are predicted by simple contextual rules. The soft pronunciations /ʒ/ or /s/ are assigned when the letters are followed by the vowels E or I, and the hard pronunciations /g/ or /k/ generally apply in the other cases. These G-C regular words were inconsistent regarding the pronunciation of the G or C, and all items had frequent enemies. For instance, the C is pronounced /s/ in the unfamiliar target word EXCISER (to excise), but /k/ in the frequent neighbour EXCUSER (to excuse). As for exception words with frequent enemies, it can be expected that regular G-C words will suffer from the activation of inconsistent phonology.

In addition to the immediate naming task, the experiment included a delayed naming task to control for the ease of articulation between the stimulus sets.

METHOD

Subjects

Twenty-eight university students at the Free University of Brussels took part in the experiment for partial fulfilment of a course requirement. Sixteen participated in the immediate naming task and 12 in the delayed naming task. AIl were native French speakers.

Stimuli

Four categories of French exception words were used : familiar words, unfamiliar words with high-frequency enemies in the orthographic neighbourhood, unfamiliar words with low-frequency enemies in the neighbourhood, and unfamiliar words without enemies in the neighbourhood

The stimuli were mono- or multi-syllabic French words. A hallmark of the studies examining the consistency effect is to use English monosyllabic words and to rely upon the body notion to define regularity (e.g. Seidenberg et al., 1984; Taraban & McClelland, 1987). There are two, not necessarily independent, reasons to prefer body-regularity to grapheme-regularity. First, the categorisation of short monosyllabic items as a function of body pronunciation also takes the phonological neighbourhood congruity into account. By contrast, neighbourhood is never considered by the grapheme-regularity notion.[1] Second, in skilled readers, naming performance appears to be more dependent upon body-regularity than grapheme-regularity (e.g. Kay & Bishop, 1987; ShaIlice et al., 1983). However, contrary to monosyllabic words, there is no consensus on how to analyse the spelling-to-sound structure of multisyllabic words. For example, to include consonant context, Jared and Seidenberg (1990; see also Tousman & Inhoff, 1992) categorised words as exceptions when the syllable is pronounced differently than it would be in isolation. Another proposal has been put forward by Taft (1991), who considered the body of the syllables, and essentially the BOSS body.

Whenever possible, the words used in the present experiment were categorised as exceptions on the basis of the pronunciation of the body (and of the body of the syIlable containing the irregularity for multisyllabic words). However, the body criteria cannot be applied to all French words. Indeed, besides the fact that irregularities are far less numerous in French than in English, they frequently concern consonants (or consonant clusters) that occur either at the beginning or at the end of the syllable (e.g. the initial grapheme CH- of the word CHAOS is pronounced /k/ instead of /ʃ/ as in CHAT). Therefore, to take the surrounding context into account in the case of an irregular initial segment, the words were considered as exceptions when the onset + vowel unit was generally pronounced differently. A special case is constituted by monosyllabic words without enemy neighbours. Because the body does not receive an alternative pronunciation, strictly speaking these words are consistent. These items are nevertheless exception words, since, consider-

[1] If lexical knowledge contributes to phonological conversion, the probability of correct pronunciation of the irregular vowel could depend more on the strength of the alternative phonological codings when they are computed from the orthographic neighbourhood than when they are computed from the overall vocabulary.

ing the immediately adjacent context, the pronunciation of the irregular segment is unique.[2]

Although *orthographie neighbour* has generally been defined as any word of similar length that can be generated by replacing a single letter (Coltheart et al., 1977), phonological congruity is usually estimated with reference to the set of words sharing the same body but not necessarily of similar length. To assess the role of lexical neighbourhood while taking phonological congruity into account, it thus seems preferable to extend slightly the notion of neighbourhood beyond the particular subset of words of similar length.

To examine the neighbourhood characteristics of each target word, the following criteria were adopted. Two words were regarded as neighbours if the number of orthographic changes did not exceed a third of the word length (in numbers of letters). Thus, one change was allowed for words three to five letters long and two changes for words six to eight letters long. The possible alterations were: (a) letter substitution preserving letter position (e.g. CLEF and CHEF); (b) transposition of two adjacent letters (e.g. ONCE and NOCE); (c) addition of a single letter (e.g. OIGNON and MOIGNON); and (d) deletion of a single letter (e.g. QUARTZ and QUART). Neighbours were never shorter nor longer than the target word by more than one letter. Neighbours were categorised as enemies when they shared the irregular orthographic unit, but not its phonological counterpart, with the target word. Neighbours were categorised as friends of the exception words when they included the same orthographic unit, also pronounced irregularly. Table 1 shows, for each exception word category, the summed log frequencies (from Imbs, 1971) of friends and enemies and the summed log frequencies of friends and enemies more frequent than the target word. Because several target words were missing from the frequency tables, familiarity instead of objective frequency was used.[3] Familiarity was assessed by asking 15 subjects who did not participate in the experiment to rate each target word on a 6-point scale (from 1 = unknown to 6 = very frequent).

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[2] There were two such words in the material [e.g. CLERC (/klɛr/) where the final C is not pronounced in French]. In both items, the irregularities concemed the final consonant clusters and were unique in the sense that the clusters never occurred in other words with the same preceding vowel. However, these clusters are pronounced differently in the other words [e.g. PARC (/park/)]. With multisyllabic words, the problem of dissociating enemy neighbourhood and irregularity does not arise, given that only a small part of the whole letter string is taken into account to define regularity.

[3] To compute the neighbourhood characteristics for the target words that did not appear in the Imbs (1971) frequency tables, the target word frequencies were estimated by comparison with words of similar familiarity.

TABLE 1
Characteristics of the Stimuli (Mean Values)

Word Category	*Length in Letters (and Syllables)*	*Log Bigram Frequency*[a]	*Familiarity*	*Summed Log Frequency of Friends (and of Friends more Frequent than the Target)*	*Summed Log Frequency of Enemies (and of Enemies more Frequent than the Target)*	*Mean Probability of the Irregular Pronunciation*[b]
Familiar						
Exception	4.6 (1.4)	3.0	5.5	1.0 (0.8)	3.5 (1.8)	0.227
Regular controls	4.6 (1.5)	3.1	5.4			
Unfamiliar						
Exception/frequent enemies	5.3 (1.7)	2.8	3.0	0.1 (0.1)	4.4 (4.4)	0.022
Regular controls	5.3 (1.7)	3.0	3.0			
Exception/rare enemies	5.3 (1.9)	2.9	3.2	0.1 (0.1)	0.7 (0.4)	0.018
Regular controls	5.4 (1.8)	3.0	3.4			
Exception/without enemies	6.1 (2.2)	2.9	3.1	0.1 (0.1)	0.0 (0.0)	0.110
Regular controls	5.8 (2.0)	3.0	3.2			
Regular GC/frequent enemies	5.3 (1.9)	3.1	3.3	6.3 (1.4)	2.8 (2.7)	
Regular controls	5.3 (2.0)	3.0	3.3			

[a] Bigram frequencies were taken from Content and Radeau (1988). [b] Based on frequency counts.

In addition to the friend/enemy counts, the frequencies of the irregular and of the regular pronunciations of the orthographic unit (body or onset + vowel unit) irregularly pronounced in the exception words were also computed. Contrary to the friend/enemy counts that were based on a subset of the vocabulary (the neighbours), the relative strengths of regular and irregular correspondences were derived from the entire word corpus, including more than 35,000 entries (Content, Mousty, & Radeau, 1990). The mean probabilities of the irregular pronunciations of the critical orthographic units are given in Table I.

The l3 exception words[4] in each category were matched as closely as possible with 13 regular words in terms of their mean numbers of letters, mean bigram frequency and mean familiarity. The summary statistics are presented in Table 1.

Finally, a fifth category of items consisting of 13 unfamiliar regular words that contained either the letter G or the letter C was included in the list of stimuli. A first characteristic of these items was that they had at 1east one neighbour of higher frequency that also contained the letter G or C (e.g. EXCISER and EXCUSER, SAGA and SAGE). A second characteristic was that the letter following the G or the C differed in the target and in its neighbour in such a way that the pronunciations of the G or C also differed (i.e. the words were enemies). As previously noted, the alteration of the G or C pronunciations when changing the following letter results from the fact that, in French, the pronunciation of the G and C is defined by contextual rules. The soft pronunciations (/ʒ/ or /s/) are used before the vowels E or I, and the hard pronunciations (/g/ or /k/) before the other vowels and the consonants (except for the bigram GN pronounced /ɲ/). Table 1 shows the neighbourhood characteristics of the target words in terms of friends and enemies defined according to the pronunciation of the letters G or C. The l3 regular words containing the letters G or C were matched with 13 regular controIs (see Table 1).

Procedure

The 140 experimental stimuli were divided into two lists of identical length. Order of presentation of the two lists was counterbalanced across subjects. The experimental session began with 16 practice trials. The stimuli were displayed in upper-case characters on a video monitor. Presentation and timing were controlled by an Apple Ile connected with a

[4] The experiment was initially run with 14 words per category. However, owing to the miscategorisation of one exception word, one item was removed from each category.

voice key. Each trial began with a warning signal (a ''+'' sign) presented for a duration of 200 msec, followed by an empty screen for 200 msec. The stimulus was then displayed in the centre of the screen. In the immediate naming task, the subjects were told to read the word aloud as quickly and accurately as possible when it appeared on the screen. The words remained on the screen until the response was made or for a maximum of 2 sec. In the delayed naming task, the subjects were instructed to wait until the response cue (a horizontal bar) was displayed before pronouncing the letter string. When the stimulus appeared, the subject had as long as desired to silently read the letter string. He or she then decided to remove the stimulus by pressing a button on the computer keyboard. The response cue was presented 1 sec after the removal of the stimulus. The time elapsing between the display of the stimuli (in the immediate naming task) or the onset of the response cue (in the delayed naming task) and the triggering of the voice key was recorded by the computer. Naming errors were recorded by the experimenter. The inter-trial interval was 1 sec.

Finally, the exception words that were regularised in the immediate naming task were presented a second time to the subjects. The items were printed on a sheet of paper and the subjects were asked to read them aloud without time constraint. This final part of the experiment was introduced to assess whether the regularisation errors observed in the immediate naming task were genuine errors, or if they were due to the fact that the subject normally used an atypical (regular) pronunciation of the irregular word [e.g. the regular pronunciation /krɔk/ of the exception word CROC (fang) was supposed to be the correct one for one of the subjects]. Knowledge of the low-frequency stimuli was also controlled for each subject.

RESULTS

Naming latencies corresponding to erroneous triggering of the voice key (those smaller than 300 msec or longer than 950 msec in the immediate naming task, and those smaller than 160 msec or longer than 750 msec in the delayed naming task) were left out of the analysis. This led to the rejection of 4.1% and 7.7% (from which 28% corresponded to very quick responses) of the words in the immediate and the delayed naming tasks, respectively. Immediate naming latencies corresponding to errors (4.7%) were discarded from the analysis, as were response times corresponding to words unknown by the subjects or corresponding to atypical pronunciations of exception words. All incorrect pronunciations of the target words were considered to be errors except when the target was unknown or when the correct (irregular) pronunciation of the exception

TABLE 2
Mean Naming Latencies (msec) in the Immediate and the Delayed Naming Tasks and Percentages of Errors (%Err) and Regularisation Errors (%RErr) in the Immediate Naming Task

Word Category	*Immediate*			*Delayed*
	Latencies	*%Err*	*%RErr*	*Latencies*
Familiar				
Exception	507	3.4	2.9	352
Regular controls	479	0.5		346
Unfamiliar				
Exception/frequentenemies	547	14.9	11.1	355
Regular controls	490	0.5		355
Exception/rare enemies	508	10.1	10.1	352
Regular controls	506	2.4		339
Exception/without enemies	501	6.3	5.8	334
Regular controls	516	1.4		346
Regular GC/frequent enemies	539	5.8		356
Regular controls	495	1.4		361

Note: The delayed naming task was performed without any error.

word was unknown; that is, when the subject had an atypical (regular) pronunciation of the exception word. Mean naming latencies, percentages of errors, and percentages of regularisation errors are presented in Table 2. Note that the longer reaction times (RTs) for the controls of the unfamiliar words with rare enemies and for the unfamiliar words without enemies resulted from very long latencies for one item in each category . When these two items were removed, the means dropped to 492 and 508 msec, respectively. Analyses by subjects (F_1) and by items (F_2) were performed both on naming latencies and on errors.

Immediate Naming latencies

An overall analysis of variance (ANOVA) including the factors *category* (familiar words; unfamiliar words with frequent enemies; unfami1iar words with rare enemies; unfamiliar words without enemies; unfami1iar words including the letters G or C) and *target type* (test words, control words) was carried out on the RTs in the immediate naming task.[5] There was a main effect of target type $[F_1(1,15) = 21.24$, MSe = 22,114,

[5] Because there was no correct RT to one word in immediate naming, the item analyses included 12 (instead of 13) unfamiliar exception words with frequent enemies.

P<0.001; F_2(1,119)= 10.18, MSe=20,999, *P*<0.01]. The factor category was significant in the subjects ana1ysis [F_1(4,60) = 4.03, MSe = 3,254, *P* < 0.025], but not in the items ana1ysis (*P* = 0.07). There was a re1iab1e interaction between target type and category [F_1(4,60) = 9.09, MSe = 6,948, *P* < 0.001; F_2(4,119) = 3.06, MSe = 6,303, *P* < 0.025]. Within each category, p1anned comparisons were performed between test and contro1 words. The difference between fami1iar regu1ar words and exception ones was significant in the subjects ana1ysis [F_1(1,15) = 20.98, MSe = 6,555, *P* < 0.001], but not in the items ana1ysis (*P* > 0.10). Unfami1iar exception words with frequent enemies were pronounced more slow1y than regu1ar contro1s [F_1(1,15) = 18.47, MSe = 25,992, *P* < 0.001; F_2(1,119) = 13.55, MSe = 27,952, *P* < 0.001]. Converse1y, the factor target type was non-significant both for unfami1iar exception words with rare enemies and for unfami1iar words without enemies. Fina1ly, naming 1atencies for unfami1iar words inc1uding the 1etter G or C were longer than for matched controls. The difference was significant in both the subjects analysis [F_1(1,15) = 20.13, MSe = 15,620, *P* < 0.001] and the items analysis [F_2(1,119) = 5.95, MSe = 12,278, *P* = 0.025].

Separate analyses including the factors *enemy frequency* (frequent, rare, or no enemies) and *regularity* (regular, exception) were performed to examine the role of enemy frequency on naming unfamiliar exception words. The factor regularity was significant in the subjects [F_1(1,15) = 5.40, MSe = 5,340, *P* < 0.05] and the items [F_2(1,119) = 4.14, MSe = 8,546, *P* < 0.05] analyses. Finally, as shown in Fig. 1, a reliable interaction was obtained between regularity and enemy frequency

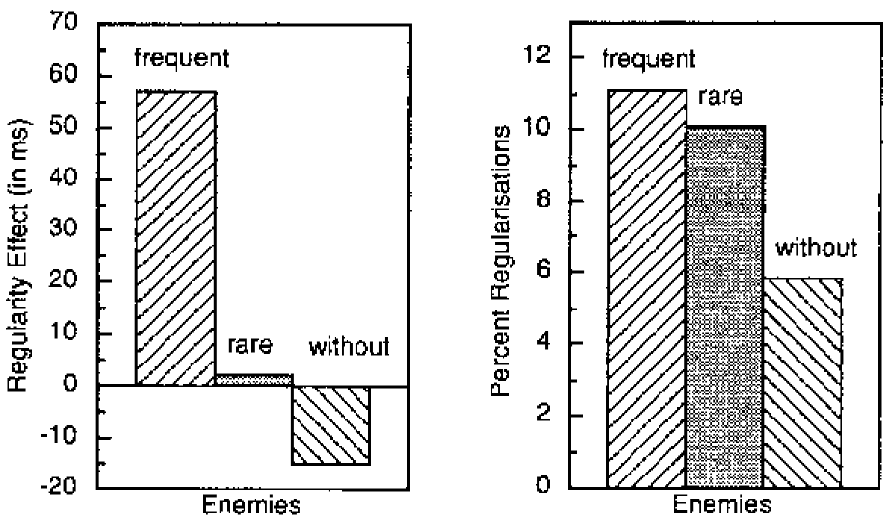

FIG. 1. Size of the regularity effect (differences between exceptions and controls) on naming latencies (left) and percent regularisations (right) for unfamiliar words.

[$F_1(2,30)=11.09$, MSe=11,196, $P<0.001$; $F_2(1,119)=5.45$, MSe= 11,246, $P < 0.05$].

Delayed Naming Latencies

Analyses of variance similar to those performed on the immediate naming latencies were carried out on the delayed naming 1atencies. The results did not reveal any significant main effects or interactions.

Errors in Immediate Naming

Similar analyses were carried out on the number of errors in the immediate naming task. The overall ANOVA including the factors category and target type showed a main effect of type [$F_1(1,15) = 47.29$, MSe = 31.51, $P < 0.001$; $F_2(1,120) = 23.76$, MSe = 38.78, $P < 0.001$]. Category was reliable by subjects [$F_1(1,15) = 4.07$, MSe = 2.84, $P < 0.05$], but not by items ($P = 0.08$). The interaction between category and target type was significant by subjects [$F_1(4,60) = 3.52$, MSe = 2.85, $P < 0.05$], but not by items ($P = 0.08$). The p1anned comparisons between familiar regular and exception words approached significance in the subjects ana1ysis only [$F_1(1,15) = 4.35$, MSe = 1.12, $P = 0.54$]. Errors were more numerous for unfami1iar exception words with frequent enemies than for regular controls [$F_1(1,15) = 16.30$, MSe = 28.12, $P < 0.01$; $F_2(1,120) = 21.21$, MSe = 34.62, $P < 0.001$]. Unfamiliar exception words with rare enemies were also more prone to errors than regular controls [$F_1(1,15) = 8.57$, MSe = 8.0, $P < 0.05$; $F_2(1,120) = 6.03$, MSe = 9.85, $P < 0.025$]. The difference between unfami1iar exception words without neighbours and regular controls was significant by subjects [$F_1(1,15) = 7.98$, MSe = 3.12, $P < 0.025$], but not by items ($P > 0.10$). Finally, the difference in the number of errors between the unfamiliar regular words containing the letters G or C and the controls was almost significant in the subjects analysis only [$F_1(1,15) = 4.23$, MSe = 2.53, $P = 0.058$].

The role of neighbourhood frequency on errors for unfamiliar exception words was examined as in the RT ana1ysis. There was a main effect of regularity [$F_1(1,15) = 47.42$, MSe = 32.67, $P < 0.001$; $F_2(1,120) = 23.76$, MSe = 38.72, $P < 0.001$]. Enemy frequency was not reliable. Furthermore, the small decrease in the regularity effect on errors as a function of enemy frequency was not significant (F_1: $P = 0.08$; F_2: $P = 0.20$).

DISCUSSION

In summary, a regularity effect in naming latencies was observed for unfamiliar words with frequent enemies but not for unfamiliar words with rare or no enemies (see Fig. 1). A non-significant advantage of regular over irregular words was also observed with familiar words. Finally, regular words including the letters G or C and having frequent enemies took longer to pronounce than did controls. The detrimental effect of enemy frequency on latencies stands in contradiction with Brown's (1987) claim that alternative phonological codes do not compete during print-to-sound mapping. According to Brown, the disadvantage of irregular words in comparison to regular words is due to the higher frequency of the graphophonological correspondences for the latter. This account does not apply to the present data, since unfamiliar words with frequent and rare enemies differed neither in terms of the frequency of friends (see Table 1) nor in terms of the frequency of the analytical correspondences. For each item, the summed frequency of alI words that include the critical irregular unit was computed. On average, the frequency (per million) of the irregular pronunciation was 321 for the unfamiliar words with frequent enemies, and 270 for the unfamiliar words with rare enemies. In fact, contrary to Brown's hypothesis, the analytical correspondences were slightly more frequent for words with frequent enemies than for words with rare enemies. The results thus support the assumption that the phonological characteristics of orthographic neighbours enter into the process of phonological translation. Competition between alternative phonological codes is stronger when the letter strings have frequent enemies than when they have infrequent or no enemies.

One might suggest, as an alternative interpretation of the data, that the longer latencies for unfamiliar words with frequent enemies originate in the process of lexical identification. Using the *N* metric to define orthographic neighbourhood, Grainger (Grainger, O'Regan, Jacobs, & Segui, 1989; Grainger & Segui, 1990) showed that word identification was delayed when the target had one or several orthographic neighbours of higher frequency. Because unfamiliar exception words were categorised as a function of enemy frequency, one might expect that frequency of the orthographic neighbours also varied across word categories. Thus, if--as assumed by dual-route theory--correct pronunciation of irregular items requires access to the orthographic lexical entries and retrieval of the whole phonological code, then words having higher frequency enemies could have endured more orthographic lexical competition than words having rare enemies. This hypothesis is unlikely for several reasons. First, in Grainger's (1990) data, the naming of Dutch words was not affected by the existence of frequent orthographic neighbours; in fact, a small facilitatory effect emerged. Nevertheless, given the high graphophonological regularity of Dutch, it is probable that the words were regular, and lexical identification was therefore unnecessary for correct pronunciation. More importantly for the present context, examination of the stimuli showed that, putting the phonological characteristics of the neighbours aside, the irregular items with rare enemies also had one or several orthographic neighbours of higher frequency. If competition between the target and the neighbours had occurred during word identification, the effect should have been similar for each word category. Finally, using the *N* metric, words with frequent enemies were partitioned as a function of the presence or the absence of orthographic neighbours of higher frequency. It appeared that the items with no higher frequency neighbour (n = 5) and the words with at least one higher frequency neighbour (n = 8) yielded similar RTs (561 and 557 msec, respectively).

A different proposaI, set in terms of dual-route theory, might be that the enemy frequency effect does not reflect lexical involvement *per se*, but rather covariations of the strengths of the irregularities at the analytical level. Since monosyllabic words served as stimuli in most studies, the categorisation of words according to friend and enemy frequency is confused with a categorisation based on the relative frequencies of the regular and the irregular pronunciations of the body. Such was not the case in the present study. As Table 1 indicates, unfamiliar words with frequent and rare enemies were not distinguishable in terms of the relative frequencies of the alternative codings of the irregular unit. However, the manipulation of regularity with multisyllabic words imposes additional constraint. Indeed, it has recently been reported that phonological translation was affected more by early than by late irregularities (Coltheart & Rastle, 1994; Content, 1991; Content & Peereman, 1992). The serial position of the irregular correspondence was determined for the unfamiliar words with frequent or rare enemies. On average, the irregularity occurred slightly earlier for the items with frequent enemies (mean position 3.1) than for the items with rare enemies (3.7). One might ask whether the disadvantage of the words with frequent enemies relative to the words with rare enemies was not caused by the presence of irregularities occurring earlier in the former than in the latter. Besides the fact that the difference in serial position is very small, there are several reasons to discard this hypothesis. First, although exception words with frequent or rare enemies differed on naming latencies, they did not diverge on regularisation rates. If the items with frequent enemies were disadvantaged because of their early irregularities, then more regularisation errors should have occurred for these items than for those with rare enemies (see Content, 1991; Content & Peereman, 1992). Second, a post-hoc analysis was carried out to examine whether the RT difference between the items with frequent or rare enemies still persisted when both categories were matched on the irregularity position. Two items were removed from each word set to match the categories (two words with the earliest positions for the set of items with frequent enemies; two words with the latest positions for the set of items with rare enemies). The mean position of the irregularities for the remaining stimuli was 3.5 for the exception words with frequent enemies and 3.4 for the exception words with rare enemies. The difference between the corresponding RTs (564 and 516msec, respectively) was still significant ($P < 0.05$). This result provides evidence that the longer latencies for items with frequent enemies compared to items with rare enemies does not follow from differences in the regularity position.[6]

The data also show that exception words with rare enemies caused more errors (essentially regularisations) than controls, while at the same time not suffering significantly from longer naming latencies. Such a differential effect of regularity on errors and latencies has already been described in some studies for high-frequency words (e.g. Content & Peereman, 1992; Taraban & McClelland, 1987; Waters, Seidenberg, & Bruck, 1984). More interestingly, enemy frequency affected latencies, but not the number of regularisations. The smaller regularisation rate observed for words with no enemies might be due to the higher probability of the irregular pronunciation (see Table 1). Within the framework of dual-route theory, a simple account of these findings can be given in relation to the time-course of activation of lexical and analytical knowledge. On the one hand, naming latencies corresponding to correct pronunciations are affected in the main by the time required for the lexical knowledge to override the erroneous phonological code (in the case of irregular words) derived from analytical knowledge. Lexical information should be phonologically less ambiguous when the exception word has few and infrequent regular enemies. Therefore, the time needed for the lexical information to outweigh the incorrect phonological code should be shorter for words with rare or no enemies than for words with frequent enemies. On the other hand, regularisation errors result from fast naming on the basis of the most frequent (regular) analytical correspondences. In fact, the regularisations of the unfamiliar exceptions were as fast as the correct pronunciations of the regular words (500 and 503 msec, respectively). Furthermore, the similar number of regularisations observed for the irregular words with frequent or rare enemies suggests that the incorrect pronunciation occurred before enough phonological evidence from

[6] *Post-hoc* analyses on latencies and on regularisation rates were directed at examining the effect of regularity position over the whole set of unfamiliar words. The items were placed in three categories: words with the irregularity on the first or second phoneme (Position 1), the third and fourth phoneme (Position 2), and the fifth phoneme or beyond (Position 3). The factor *position* was not significant. There was a small trend towards longer latencies for Positions 1 and 2 than for Position 3 (529, 537 and 501 msec, respectively), but on regularisations only Position 2 tended to be more affected by irregularity than Position 3 (7, 12 and 8% of regularisations, respectively).

TABLE 3
Mean Naming Latencies (msec) Corresponding to the Regularisation Errors and to the Correct Pronunciations of the Same Items

Word Category	*Regularisation*	*Correct Naming*	*Difference*
Exception/frequent enemies	505	587	82
Exception/rare enemies	506	552	46
Difference	-1	35	

the lexical level had accumulated to override the code built from analytical knowledge. This proposal leads to the prediction that the RTs corresponding to the regularisations should be unaffected by the enemy frequency. Because there were few regularisations of the irregular items having no enemies, only items with frequent or rare enemies were used in the analysis. As Table 3 shows, while latencies for correct pronunciations varied as a function of enemy frequency, such was not the case for the RTs corresponding to the regularisations. Table 3 also indicates clearly that if regularisation latencies are used to estimate the time necessary to assemble a phonological code from analytical correspondences, the additional time required for lexical knowledge to override it depends on the degree of phonological dissension among the lexical neighbours.

Competition between alternative phonological codings seems also to occur in the case of the regular words including the letters G or C. Indeed, it turned out that naming latencies for these words were longer than those for controls. Given that the pronunciation rules for these letters are clearly defined, the analytical process should generally lead to a correct phonological code. However, since the G-C words have very frequent enemies supporting an erroneous pronunciation of the critical letter, some evidence should accumulate in favour of the incorrect phonological code and temporarily lessen the weight of the correct one. Therefore, latencies corresponding to correct responses should be slower, and erroneous coding of the critical letter should occur on some occasions. As a matter of fact, there were 4.8% of errors consisting in an incorrect pronunciation of the critical letter [e.g. EXCISER pronounced /ɛkskize/ instead of /ɛksize/ due to its similarity with EXCUSER (/ɛkskyze/)].

Taken together, the present results add some support to the assumption that print-to-sound conversion relies upon the knowledge of how orthographically similar words are encoded. Efficiency of the processes depends on the degree of phonological ambiguity resulting from the phonological dissension among the lexical neighbours. The data also suggest that the influence of lexical knowledge during phonological translation develops over time in such a way that the earlier encoding is only affected by the characteristics of the analytical correspondences. This last aspect could have been obscured in previous studies because of the use of short monosyllabic words whose characteristics in terms of analytical correspondences and of neighbourhood are largely confused. How can current theories explain the present set of data? In the case of a dual-route architecture such as that espoused by Coltheart et al. (1993), the knowledge of the pronunciation of the lexical neighbours and the analytical knowledge of the correspondences between orthography and phonology are pooled in a common buffer. Longer latencies for exception words result from the conflict between the phonological hypotheses derived from grapheme-to-phoneme correspondences and from lexical activation of the target and its neighbours. Hence, activation of frequent enemies in the lexical neighbourhood should slow down the build-up of activation of the correct phonological code. To account for the observation that neither the regularisation rates nor the corresponding RTs were influenced by enemy frequency, one can suppose that regularisations arise when a phonological description based on the most frequent analytical correspondences is quickly derived before any major influence from the lexical level occurs.

According to the PDP approach, there are no separate sources of knowledge, as is the case for the lexical-analytical distinction. In Seidenberg and McClelland's (1989) network, the connection strengths between orthographic and phonological units are not only related to the number of times a specific word has been encountered during learning, but also to the number of times orthographically and phonologically similar words have been presented. Through the back-propagation algorithm, words that are orthographically and phonologically similar reinforce the same connections. However, when an orthographic neighbour with a divergent pronunciation is presented, all connection weights are updated to minimise the gap between the produced and the expected phonological outputs. The strengths of the connections between orthographic and phonological units are thus sensitive to the frequency of occurrence of the alternative codings. Within this context, phonological conversion is directly affected by the relative frequencies of friends and enemies. Irregular words with rare enemies benefit from stronger connections between orthographic and phonological units than irregular words with frequent enemies.

Although Seidenberg and McClelland's model was designed to process monosyllabic words, neighbourhood effects on multisyllabic words can also be expected, because both the frequencies of the alternative codings and the context in which the orthographic unit occurs are relevant in the setting of the connection weights. However, whether or not the general model can account for the absence of the enemy frequency effect on regularisation data remains an open question. Indeed, for simplicity of implementation, the network processed the letter strings in a single step. The phonological error score--which reflects the differences in the activation of the phonological units between the produced and the expected outputs--served to simulate both naming latencies and error data. Therefore, as discussed by Kawamoto and Kitzis (1991), the more probable a pronunciation is, the faster it should occur. The model implemented thus erroneously predicts that latencies corresponding to irregular pronunciations of exception words (which occur most of the time) should be shorter than latencies corresponding to the regular pronunciations. This was neither the case in Kawamoto and Zemblidge's (1992) study nor in the present experiment (see Table 3). Furthermore, since the magnitude of the error score is affected by the target's resemblance to phonologically divergent words, one should predict an effect of enemy frequency both on latencies and on regularisation errors.

To account for the present set of data, one can propose that during the time-course of activation of the phonological units, a first pattern of activation emerges reflecting the most frequent (regular) correspondences between orthography and phonology. The information provided by the context adjacent to the orthographic units would gradually constrain the activation of the units in such a way that the correct pronunciation (irregular for exception words) could take precedence over the regular one. A first step in this direction is found in the dynamical system recently described by Kawamoto (1993; Kawamoto & Zemblidge, 1992). The network encodes orthographic and phonological information as well as parts of speech and semantic attributes. Each unit is reciprocally connected with the other units, and the activation levels are updated on each iteration through recurrent connections. The time-course of activation of the irregular (/beis/) and regular (/bas/) phonological codes for the homograph BASS has been depicted after training the network with both pronunciations as well as with three other regular words (MASS, LASS, PASS). The simulation data showed that the regular pronunciation was activated most during the first iterations, but its activation subsequently decreased as the activation of the irregular pronunciation approached the maximum. Hence, the model correctly predicts that regular pronunciations of exception words occur more quickly than irregular pronunciations. However, without simulation, it remains unclear whether the model could account for the finding that enemy frequency affected the slower (irregular) pronunciations, but not the faster (regular) pronunciations. One possibility may be that early phonological computation is based on the stronger connections between orthography and phonology and is free of any major influence of the contextual information on unit activation. An observation compatible with this hypothesis is that the regular pronunciation of the word BASS was initially activated more than the irregular pronunciation despite its less frequent occurrence in the training corpus. Through the recurrent connections, the orthographic context could then gradually place additional constraint on unit activation. The move to the final state of the network should therefore be affected by the frequency of the alternative phonological codes that correspond to similar patterns of activation over the orthographic units. Finally, an addition reason that might explain why enemy frequency had no effect on the regularisation data is related to the fact that most of the stimuli were multisyllabic. It has been claimed that syllables act as processing units during reading, although it is unclear whether syllabication results from explicit segmentation (e.g. Spoehr & Smith, 1973) or from the statistical properties of the system (Seidenberg, 1987). If early phonological computation is based on syllable-like units, then processing should depend more on the relative frequencies of the alternative codings at the syllabic level than on the neighbourhood characteristics of the whole letter string.

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