Further explorations of the consistency effect in word and nonword pronunciation

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Three experiments explored the consistency effect in word and nonword pronunciation. All three experiments involved a common second phase in which subjects were required to pronounce a sequence of consistent and inconsistent words and nonwords. The experiments were distinguished by the nature of Phase 1. In Experiment 1, subjects pronounced a sequence of words and nonwords in which all the words were exceptions. In Experiment 2, all the items in this phase were consistent, and in Experiment 3, they were inconsistent. Consistency effects for words, as measured by pronunciation latency, were confined to Experiment 1. Consistency effects for nonwords were found in Experiment 2. No consistency effects were found for either words or nonwords in Experiment 3. There was clear evidence of a consistency effect for nonwords in Experiment 1 in terms of pronunciation errors, but the latency data were not significant. This is attributed to the very slow response times in this condition. All these data are compatible with both revised analogy and dual-route theories.

Two classes of theory seek to explain the processes whereby the pronunciation of words and nonwords is achieved: the dual-route theory and the analogy theory. The former, as originally proposed by Coltheart (1978) and subsequently developed by Morton and Patterson (1980) and Parkin (1984), postulates two functionally independent methods of word processing. One of these is a lexical processing route that operates by the direct mapping of the visual characteristics of a letter string onto its stored lexical representation in the mental lexicon. In addition, a nonlexical processing route is assumed to translate the visual code of a word into a phonological one on the basis of spelling-to-sound rules. Coltheart proposed that this phonemic transcription operated by means of grapheme-to-phoneme correspondence rules (GPCs) as specified by Venezky (1970). These rules were derived by considering a maximum of two letters at a time (i.e., vowel, vowel digraph, consonant, and consonant clusters) to define their major and minor correspondences. For example, the major correspondence (i.e., the most common pronunciation) of the vowel digraph EA is /i/ as in BEAN, and minor (less common) ones are /ei/ as in BREAK and /e/ as in BREAD. Thus the phonemic transcription of the word BEACH would yield /b/, /i/, and /tʃ/.¹

Recent modifications to dual-route theory have amended Coltheart's (1978) assertion that the nonlexical route operates solely by the application of GPCs. Shallice, Warrington, and McCarthy (1983) and Parkin (1984) suggested that nonlexical assembly of phonology may also use larger patterns of letters operating beyond the GPC level. If this is the case, some words exhibiting a minor correspondence in terms of Venezky's (1970) rules have a major corre-

spondence when larger units are considered. For example, whereas /e/ is a minor correspondence for the vowel digraph EA, it becomes, when followed by D, as in BREAD, the major correspondence. Parkin (1984) obtained no regularity effect with words that were irregular in terms of GPCs but regular when higher order rules were considered. Words such as HEALTH (parsed as H + EALTH rather than H + EA + L + TH) and SIGN (S + IGN) were found to produce pronunciation latencies similar to those of regular words. Parkin pointed out that positional constraints may also have to be considered. For example, IGN at the beginning or in the middle of a word (e.g., IGNORANT, SIGNAL) must involve quite different rules. Thus a modification to the dual-route theory may require a nonlexical spelling-to-sound route to contain these rules as well as GPCs.

Despite these developments, dual-route theory has come under attack from a number of sources. In particular, a series of experiments by Glushko (1979) provided considerable interpretive problems for the theory. Glushko studied the pronunciation of both words and nonwords and assumed that the "orthographic neighborhood" of a given word was the main factor in determining the segmentation of a letter string that subsequently led to its pronunciation. For monosyllables, the primary segmentation is consonant + "word body" (e.g., H + EAD), which therefore enables orthographic neighborhoods to be operationally defined in terms of word bodies.

Proceeding from the concept of an orthographic neighborhood, Glushko (1979) distinguished three types of words: (1) consistent words (previously termed "regular"), or those that exhibit a regular spelling-to-sound correspondence (in Venezky's [1970] terms, a major correspondence) and that are based on a word body with an invariant pronunciation in all the words in which it occurs (e.g., pINK, tEACH); (2) inconsistent words, or those that have a regular spelling-to-sound correspondence

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but that have at least one deviant visual neighbor carrying an alternative pronunciation (e.g., IEAF, fIVE); and (3) exception words, or those that have an irregular spelling-to-sound correspondence (i.e., minor GPC) but that are based on a word body regularly pronounced in other words (e.g., dEAF, gIVE).²

Glushko (1979) showed (Experiment 3) that inconsistent words produced longer pronunciation latencies than did consistent words and (Experiment 2) that nonwords based on inconsistent word bodies produced longer latencies than did nonwords based on entirely consistent word bodies. On the assumption that the pronunciation assigned by the preferential application of the regular correspondence via the nonlexical route agrees with the pronunciation derived from the lexicon, dual-route theory predicts no difference in latencies for consistent and inconsistent items. Given that the regular correspondence is applied via the nonlexical route without taking possible alternatives into account, dual-route theory did not explain Glushko's findings, and initially it seemed that no version could comfortably accommodate them.

In accounting for his results, Glushko (1979) proposed the "activation-synthesis" model of pronunciation. Essentially, it rejected the dichotomy proposed in the dual-route model and proposed instead that, when a letter string is presented, it activates words and word subsegments with the same orthographic and phonological features. The "desired" pronunciation of the complete letter string is then synthesized from this activated information.

Subsequent investigators have been more explicit about the possible workings of an analogy model. Kay and Marcel (1981) and Marcel (1980) suggested that a visually presented letter string is segmented in all possible ways, although Marcel stated that those segments producing morphemes predominate. Each segment activates the phonology of matching segments in orthographically similar words. In cases in which an orthographic segment has more than one pronunciation (e.g., -OME), a nonword with that word body (e.g., BOME) will be assigned the pronunciation that occurs in the majority of lexical exemplars. With words, the pronunciation of the complete letter string partially dominates conflicting pronunciations produced by subsegments, with any resulting delay in responding being determined by the amount of conflict these segments generate. The assumed dominance of lexical entries over other sources of information therefore allows the model to explain the relatively low rate of "regularization" errors even in words with unique spelling-to-sound correspondences (e.g., PINT → /pɪnt/).

Among other versions of analogy theory that have been put forward is that of McClelland and Rumelhart (1982). They proposed an interactive activation model, which, they acknowledged, closely resembles Glushko's (1979). Their model is based on the notion of a "cohort," whereby a word visually presented activates an orthographically determined cohort. Because it is assumed to depend on visual analysis, phonological activation lags behind, until all elements of the cohort have been elimi-

nated and the one corresponding to the input is left. McClelland and Rumelhart's model was developed further by Seidenberg, Waters, Barnes, and Tanenhaus (1984) and as such differs from Glushko's (1979) version in that it asserts the existence of sublexical orthographic-phonological associations in the word-recognition system as well as "whole-word" phonology. As Norris and Brown (1985) pointed out, however, the distinction between the analogy and dual-route theories becomes unclear if the lexicon is assumed to contain spelling-to-sound correspondences.

Notwithstanding the differences between these versions of analogy theory, there is agreement (with the possible exception of Seidenberg et al. [1984] for the reason stated above) that it differs essentially from dual-route theory in that it rejects the existence of a separate nonlexical route. Instead, the theory argues that the pronunciation of all letter strings (whether words or nonwords) is determined by a single process whereby all lexical entries sharing the visual characteristics of the input are accessed and from which the appropriate pronunciation is then synthesized. Rather than being subjected to abstract nonlexical spelling-to-sound rules by which an orthographic segment is assigned its phonology, the segments of a new word or nonword are matched to the equivalent segments in known words. Once the phonology of these segments has been accessed, the pronunciation of the complete letter string can be derived. In the case of known real words, the whole letter string is already orthographically and phonologically represented.

With these points in mind, one can apply analogy theory to explain Glushko's (1979) results. An inconsistent word activates both its own lexical entry and the alternative pronunciations from orthographically identical but phonologically different subsegments (e.g., mOVE, dOVE). Although the pronunciation of the activated lexical entry may be salient, a delay in pronunciation onset would be anticipated while the conflict generated is resolved. In the case of inconsistent nonwords, the activation of lexical entries with conflicting analogical subsegments (i.e., mOVE, dOVE) would be expected to create interference and therefore delay. With the nonword BOVE, for example, the greater number of lexical exemplars carrying the pronunciation /əʊv/ would increase the likelihood of the production of /bəʊv/.

Consistency effects in the pronunciation of words and nonwords are perhaps the most important source of evidence in favor of analogical models. It is therefore important that the exact characteristics of these effects be understood. Seidenberg et al. (1984) drew attention to an important methodological problem with Glushko's (1979) demonstration of consistency effects in real-word pronunciation. In his real-word experiment, inconsistent word bodies were repeated across the experiment, and subjects were therefore required to produce different pronunciations at various stages of the experiment. Seidenberg et al. reasoned that this repetition/variation factor may have contributed to the consistency effect. Specifically, they pro-

posed that longer pronunciation latencies for inconsistent words may have arisen, partly or wholly, because subjects were preexposed to the alternative pronunciation of the word body at an earlier stage of the experiment. Seidenberg et al. presented data that showed that longer pronunciation latencies for inconsistent words were found only when the item carrying the exception pronunciation preceded the inconsistent word in the experimental sequence (e.g., a delay with STINT occurs only if PINT comes before it in the sequence). In contrast, the commonly observed delay in pronouncing exception words was unaffected by prior exposure.

Taken alone, these data suggest that the consistency effect in real-word pronunciation depends on prior exposure of the exception pronunciation. However, Seidenberg et al. (1984) presented other data that modify that conclusion. In Experiment 4, they found a consistency effect for low-frequency words but not for high-frequency words. From these data we are therefore left with the conclusion that consistency effects occur in low-frequency words without preexposure of the exception correspondence, whereas for high-frequency words such prior exposure is necessary.

These findings suggest that the consistency effect, at least for words, is not as straightforward as was originally thought. However, Seidenberg et al.'s (1984) findings have come in for some criticism. Norris and Brown (1985) queried the small numbers of items typically used in the experiments and the fact that the materials were not matched for initial phoneme (an important source of variation in the measurement of pronunciation latencies). Furthermore, they claimed that the appropriate analysis was not performed on the data of Experiment 4 to confirm the interaction between consistency and frequency. Seidenberg (1985) replied to these criticisms; interested readers should refer to the original articles to make their own assessments of Norris and Brown's claims. We must, however, draw attention to additional features of the Seidenberg et al. experiments that might question the value of some of their findings. In their Experiment 3, there were 20 word triples, each composed of an exception word (e.g., PINT), an inconsistent word (e.g., HINT), and a consistent control (e.g., MASK). These were divided into two blocks containing 10 exemplars of each word type. An additional constraint was that both members of an exception-inconsistent pair did not appear in the same block, although their method section gives no indication that presentation of the blocks was counter-balanced. It therefore seems that consistency effects with and without prior exposure were based on different small samples of items.

Detailed analysis of the items used in the inconsistent and consistent control samples of Experiment 4 of Seidenberg et al. (1984) suggests a bias that may have partly or wholly caused the effects observed. In the low-frequency section of the materials, it is assumed that frequency was matched across the word-type variable. However, calculation of the word-frequency values indi-

cates a mean of 4.9 per million for the inconsistent words and 9.3 per million for the consistent items. At this end of the frequency range, the median values might be considered more informative. Here we find a median of 1 for the inconsistent items (range = 0-21) and 4 for consistent ones (range = 1-40). This bias in sampling, which is significant [$t(14) = 2.33$, $p < .05$, based on log-transformed scores], could well be sufficient to have caused or contributed to the observed difference.

Given the central importance of Glushko's (1979) findings to current theorizing about the nature of pronunciation assembly (e.g., Henderson, 1985; Humphreys & Evett, 1985), it is essential to determine in more detail the characteristics of consistency effects. In view of Seidenberg et al.'s (1984) results, it is important to establish the extent to which consistency effects in word pronunciation depend on prior exposure of exception words. If consistency effects occur only under conditions of prior exposure of exception words, analogy models must accommodate such an effect. Furthermore, because analogy models in their purest form assume a common process underlying word and nonword pronunciation, it is important to examine how manipulations of the prior-exposure variable affect nonword as well as word pronunciation. If there is one underlying process, prior exposure should affect words and nonwords alike. However, if words and nonwords are affected differently by prior exposure to exception pronunciations, some modification of the analogy model must be considered.

The following study represents three experiments, each consisting of two phases. Phase 2 of all the experiments was the same: Pronunciation latencies to a series of inconsistent words and nonwords were measured and compared with those for matched consistent words and nonwords. In Experiment 1, Phase 1 required subjects to pronounce a sequence of words and nonwords based on inconsistent word bodies in which all the words had exception pronunciations. In Experiment 2, Phase 1 comprised words and nonwords based on consistent word bodies. In Experiment 3, Phase 1 was composed of inconsistent words and nonwords in which the words carried the regular pronunciation. In Experiments 1 and 3, the word bodies used in Phase 1 were also used in Phase 2.

Collectively, these experiments reconsidered the original findings of Seidenberg et al. (1984, Experiment 3) and extended them by considering nonword pronunciation. In addition, Experiment 3 allowed a more detailed appraisal of how prior exposure of inconsistent word bodies influences latencies when pronouncing inconsistent words and nonwords. Table 1 summarizes the design of these experiments.

METHOD

Subjects

The subjects were 48 members of the staff and student population of the University of Sussex; they were paid for participating.

Table 1
Outline of the Experimental Design

	Phase 1		Phase 2	
Experiment 1	PINT	YINT	HINT FEED	FINT ZEED
Experiment 2	HATE	JATE	As above	
Experiment 3	MINT	RINT	As above	

Sixteen subjects were allocated randomly to each experiment. All had normal or corrected-to-normal vision. The subjects spoke English as their mother tongue, and none had strong regional accents.³

Materials

The same test items were used in all three experiments. Twenty-eight monosyllabic inconsistent words, either four or five letters long, were chosen. For each of these, a nonword based on the inconsistent word body was constructed by changing the initial phoneme of the inconsistent word (e.g., DOME, BOME). A monosyllabic consistent word and a nonword, matched for length, initial phoneme, and word frequency (Kučera & Francis, 1967), were chosen for each inconsistent item. In cases in which close word-frequency matches were impossible, the consistent words were of lower frequency than were the inconsistent ones to which they were matched. This was done to avoid the possibility of the results' being interpreted as a consequence of the higher frequency of some consistent words, rather than the experimental manipulation itself. The median frequency for the consistent words was 14.5 per million (range = 1-171); that for the inconsistent words was 14 per million (range = 0-750). All the experimental items are shown in Appendix A.

As described above, the experiments were distinguished by the contents of Phase 1. Items for this phase were selected according to the defining criteria for each experiment. These items are shown in Appendix B.

Apparatus and Procedure

The apparatus and procedure used were identical for all three experiments. The experiments were programmed on a PDP-11/40 computer interfaced with a Motorola M6800 microprocessor. The subjects sat in a soundproof cubicle and faced a 9-in. video monitor. The instructions given were the same in all three experiments. The subjects were told that they would be presented with a series of individual words and nonwords, each one syllable and either four or five letters long. They were to pronounce the items as quickly and as accurately as possible. The subjects were told that there were six sections to the experiment and that each was a random sequence of real words and nonwords. They were informed that after each section they could have a break and should press the "yes" button in front of them when they were ready to continue.

The items were presented in uppercase letters and subtended a visual angle of approximately 1°. Each trial began with the presentation of a word or nonword, which remained on the screen until the subject had pronounced it or until the default value of 1,200 msec had elapsed. Pronunciation latencies were recorded using a voice key interfaced with the microprocessor.

The initial phase of the experiments, the nature of which was determined by the particular experiment to be undertaken, consisted of a random sequence of 28 words and 28 nonwords (for which pronunciation latencies were not recorded). This phase was followed by two blocks of 56 experimental trials, each block (hereafter designated Blocks 1 and 2, respectively) being preceded by two dummy trials. Each block contained an equal number of randomly arranged words and nonwords; within this constraint, there were equal numbers of consistent and inconsistent word bodies. Furthermore, no word body was repeated within the same block. Thus if HINT was presented in Block 1, its matched nonword FINT was shown in

Block 2. Blocks 1 and 2 were separated by a short self-paced rest interval. The subjects saw all blocks of trials, half with one assignment of items to blocks and half with the reverse assignment.

RESULTS

Mean pronunciation latencies for each of the experimental conditions were calculated; these data are summarized in Table 2. Individual item means are shown in Appendix A. Trials on which subjects made pronunciation errors, exceeded the default value, or accidentally activated the voice key were excluded. In cases in which the response to a particular item was excluded, the reaction time to its matched item was also discounted. Data loss amounted to 14.7% in Experiment 1, 7.3% in Experiment 2, and 7.8% in Experiment 3.

All three experiments were analyzed in the same way, using a three-way ANOVA with word body type (consistent/inconsistent), word type (word/nonword), and block (1/2) as fixed factors. For each effect in the analysis, two factors were computed, one based on subjects as the source of error variance and the other based on a by-items variance assuming a randomized design. These two values are reported for each effect (by subjects and by items, termed F_1 and F_2 , respectively), or, where significant, the corresponding $\min F'$ value is given instead. As a result of these analyses, separate analyses of the word and nonword pronunciation latency data were carried out. All main effects and interactions found by these analyses are shown in Table 3.

The number of irregularization errors, (i.e., the assignment of an irregular pronunciation to an item carrying an inconsistent string of letters, e.g., NEAF $\rightarrow$ /nef/) made by each subject were calculated; these data are summarized in Table 4. The error data from each experiment were analyzed using an ANOVA similar to that used with the pronunciation latency data, but, due to the low error rates, only subjects were used as the source of error variance. It was also necessary to conduct a separate analysis

Table 2
Mean Pronunciation Latencies (in Milliseconds) and Standard Errors of the Mean (SEMs) for Experiments 1, 2, and 3 as a Function of Word Body Type (Consistent/Inconsistent), Word Type (Word/Nonword), and Block (First/Second)

Block	Experiment 1		Experiment 2		Experiment 3	
	Latency	SEM	Latency	SEM	Latency	SEM
Consistent Words						
1	606	17.25	608	14.75	620	12.75
2	588	15	591	15.5	612	13.75
Inconsistent Words						
1	633	21.75	614	15.75	613	11.25
2	612	15.25	602	16.75	629	15.25
Consistent Nonwords						
1	658	19	626	17.25	641	16.5
2	621	16.5	609	18.75	640	15.75
Inconsistent Nonwords						
1	653	20.25	640	17.75	646	13.5
2	630	17.25	629	20.25	642	16

Table 3
Results of ANOVAs of the Pronunciation Latency Data From Experiments 1, 2, and 3 and
of ANOVAs of the Irregularization Data Using Subjects as the Source of Error Variance

Effect	Experiment		
	1	2	3
Word Body Type		$F_1(1,15)=9.44†$	
C < IC	(1,98)=4.14*	$F_2(1,108)=5.85*$	n.s.
Word Type			
W < NW	(1,72)=17.12‡	(1,90)=12.0‡	(1,101)=9.6‡
Block			
B2 < B1	(1,22)=8.41†	n.s.	n.s.
Word Body ×	$F_2(1,15)=9.37†$		
Word Type	$F_2(1,108)=3.87*$	n.s.	n.s.
Words Only			
Word Body Type			
C < IC	(1,64)=7.19†	n.s.	n.s.
Block	$F_1(1,15)=4.7*$		
B2 < B1	$F_2(1,54)=17.2‡$	n.s.	n.s.
Nonwords Only			
Word Body Type		$F_1(1,15)=5.94*$	
C < IC	n.s.	$F_2(1,54)=5.92*$	n.s.
Block			
B2 < B1	(1,27)=7.4*	n.s.	n.s.
Irregularization Error Analysis			
Word Type			
W < NW	$F(1,15)=44.5‡$	$F(1,15)=26.1‡$	$F(1,15)=59.15‡$
Block			
B2 < B1	$F(1,15)=12.95†$	$F(1,15)=5.00*$	n.s.
Word Type ×			
Block	$F(1,15)=6.4*$	$F(1,15)=9.6†$	n.s.
Nonwords Only			
Block			
B2 < B1	$F(1,15)=10.9†$	$F(1,15)=7.63*$	n.s.
Overall Irregularization Error Analysis			
Word Type			
W < NW		$F(1,15)=90.8‡$	
Block			
B2 < B1		$F(1,15)=4.58*$	
Experiments			
2 & 3 < 1		$F(2,30)=11.18‡$	
Word Type ×			
Block ×			
Experiment		$F(2,30)=5.53*$	

Note—Values shown are min F' ratios unless indicated otherwise. * $p < .05$; † $p < .01$; ‡ $p < .001$. C = consistent; IC = inconsistent; W = word; NW = nonword; B = block; F_1 = by subjects; F_2 = by items; F = by subjects (error analysis).

of the nonword errors from each experiment. In addition, the variation in errors across the three experiments was investigated. The results of these analyses are also shown in Table 3.

For clarification, the results will now be summarized. Experiment 1 showed that preexposure of words with exception pronunciations produced a reliable consistency effect for words, thus confirming Seidenberg et al.'s (1984) findings. Contrary to expectations, there was no such effect for nonwords under these conditions. Experiment 2 showed that when subjects were preexposed to items carrying only consistent pronunciations, there was no consistency effect for words but a reliable effect for non-

words. In Experiment 3, preexposure of inconsistent words carrying the regular pronunciation resulted in no consistency effect for either words or nonwords. In each of the three experiments, nonwords (whether consistent or inconsistent) produced longer latencies than words; in Experiments 1 and 2, items with inconsistent word bodies showed longer latencies than did those with consistent ones. Block 2 items yielded significantly faster latencies only in Experiment 1, and the word body type (consistent/inconsistent) × word type (word/nonword) interaction was significant only in that experiment.

The ANOVAs using subjects as the source of error variance showed that in each experiment there were signifi-

Table 4
Number of Irregularization Errors for Experiments 1, 2,
and 3 as a Function of Block

Block	Experiment		
	1	2	3
Words			
1	0	0	0
2	4	1	1
Nonwords			
1	29	16	10
2	15	7	16

cantly more irregularization errors made to nonwords than to words and more to items (whether words or nonwords) in Block 1 than in Block 2 in Experiments 1 and 2. The word type $\times$ block interaction showed a significant difference again only in Experiments 1 and 2, as did the non-word data (i.e., there were more errors in Block 1 than in Block 2).

The overall error analysis revealed highly significant effects of word type (more errors to nonwords than to words) and block (more errors in Block 1). Experiment 1 produced significantly more errors than did either Experiment 2 or Experiment 3, and the word type $\times$ block $\times$ experiment analysis was also significant.

DISCUSSION

These experiments demonstrated the limited conditions under which consistency effects occur. For words, the effect is observed only after subjects have been exposed to words carrying exception pronunciations. With nonwords, the effect is seen following exposure to consistently pronounced words but not following exposure to exception words. (This apparently anomalous finding will be considered below.) No consistency effects were found when subjects were preexposed to inconsistent words.

Before these data are discussed, one further aspect of the results must be considered. In the introduction, it was noted that Seidenberg et al. (1984) claimed to have found a consistency effect for low-frequency items when there was no prior exposure of exception pronunciations. However, it was suggested that inadequate matching in terms of word frequency may have contributed to the effect observed. Andrews (1982) reported an experiment in which pronunciation latencies to a random sequence of words and nonwords were recorded. In line with Seidenberg et al. (1984), Andrews found a significant consistency effect for low-frequency words but not for high-frequency words (nonword data were not reported). Unfortunately, Andrews's finding can also be criticized in terms of a failure to match for word frequency. Her study also collected lexical decision latencies for the materials. For the low-frequency items showing a consistency effect, the consistent items had a mean lexical decision time 51 msec faster than that of the inconsistent items. This suggests that the differences in pronunciation latency obtained may stem from mismatches in word frequency; calculation of

this variable reveals a mean frequency of 13.7 for her consistent items and 7.7 for her inconsistent ones.

Notwithstanding these difficulties, it seemed reasonable to examine whether the present data showed any evidence that word frequency influenced the effects obtained. The items were split into two groups of nine, one with words whose frequencies ranged from 0 to 3 per million and the other with words whose frequencies ranged from 46 to 750 per million. (The remaining items in the midrange were not used in the analysis.) In Experiment 1, the low- and high-frequency word groups produced consistency effects of 26 and 31 msec, respectively, thus providing no support for any influence of word frequency. In Experiment 2, which most closely resembles the experiment in which Andrews (1982) obtained a consistency effect for low-frequency items, the differences were 17 and 11 msec, respectively. A *t* test based on materials means showed that the 17-msec difference obtained with the lower frequency items was not significant [$t(17) < 1$]. Although this post hoc analysis cannot rule out potential influences of word frequency on the appearance of consistency effects, the analysis, which is based on similar frequency differences and on only one item per condition less than in Andrews (1982), suggests that the 48-msec consistency effect she obtained may have derived mainly from frequency differences between her consistent and inconsistent samples.

In addition, the major point of our paper is that consistency effects are influenced powerfully by prior exposure and word body type. This leads us to reject the "pure" analogy view put forward by Glushko (1979). If it were shown that items of very low frequency caused pronunciation delays without priming, our conclusions would not be undermined. For example, if one found significant delays to JAYS, MOOSE, and MUSH in unprimed conditions, this might reflect the extremely high thresholds needed for their internal representations to fire. Thus one might well get effects because these would be much more likely to be treated as nonwords than would their counterparts SAYS, LOOSE, and PUSH. Experiment 2 demonstrated that nonwords show consistency effects without prior exposure, and a similar explanation could be proposed to explain low-frequency unprimed consistency effects.

Analogy Theories

These theories were initiated from Glushko's (1979) demonstration of consistency effects in both word and nonword pronunciation. In the absence of any further data, his findings allowed the conclusion that pronunciations of words and nonwords were derived from a common underlying process. Seidenberg et al.'s (1984) data and those of the present study indicate that the position is more complicated and that analogy models must distinguish between the processes underlying word and nonword pronunciation. Such a distinction is inherent in the exposition of analogy theory offered by Kay and Marcel (1981). They proposed that a fully activated lexical entry will pre-

dominate in the processes governing the assembly of pronunciation. With this idea in mind, it is possible to revise analogy theory to account for the present findings. The absence of consistency effects for words with no prior exposure of inconsistent word bodies (Experiment 2) can be explained by assuming that, under conditions of no prior activation, the salience of an activated lexical entry is sufficient to suppress competing sources of analogical information. To explain the differential effects of prior exposure (Experiment 1 vs. Experiment 3), it is necessary to introduce an additional factor into the model. There is plenty of evidence that a lexical entry, once activated, can remain at an above-average level of activity for some time (e.g., Madigan, 1969). In the case of an inconsistent word, this temporary increase in activation level might serve to change the relative weight of its contribution to the analogical process. Within this kind of system, prior exposure of an exception word would increase the weight given to its pronunciation in the analogical process, thus resulting in a consistency effect for a subsequently presented inconsistent word and, as observed in Experiment 1, an increased probability of irregularization. When prior exposure involves only inconsistent words (Experiment 3), this serves to weight more heavily the regular pronunciation, so that the competing information from exception lexical entries is below the threshold required for the appearance of a consistency effect.

In the case of nonwords, prior exposure of exception words would increase the weight given to exception pronunciations in the analogical process applied to the nonwords in Phase 2 (Experiment 1). That this occurred is evident from the larger number of irregularization errors found in Phase 2 of Experiment 1. A problem, however, is the failure to detect a consistency effect for nonwords, a finding that would be expected given the error data. A possible answer to this lies in the size of the latencies for nonwords in Block 1 of Experiment 1. They average 655 msec, which is considerably higher than the average for any other condition in all three experiments. These longer latencies may indicate that, following the initial phase of Experiment 1, the subjects adopted a cautious approach to the pronunciation task because of the uncertainty about pronunciation engendered by the appearance of exceptions in the first phase. The blocks factor in the analysis supports this view. In Experiment 1, there was a significant decrease in pronunciation latency across blocks, which is consistent with subjects' growing in confidence. In contrast, Experiments 2 and 3 showed no effect of blocks, which suggests that the subjects found the task easier. Again, in Experiment 1, the delay caused by uncertainty may have led subjects to delay their responses sufficiently for any conflict in pronunciation assembly to dissipate before pronunciation was initiated. In Block 2, responding speeded up, but the reduced number of observations at this more sensitive level of reaction time may have been insufficient to detect a reliable effect.

The nonword data from Experiments 2 and 3 are less problematic. In Experiment 2, the consistency effect can

be attributed to the absence of any fully activated lexical entry that dominated the assembly of pronunciation. As a result, an inconsistent nonword was subject to all the conflicts available within the system. Because of these competing analogical sources, a delay ensued while the conflicts were resolved. When there was prior exposure of inconsistent words (Experiment 3), this weighted more strongly the regular pronunciation, to a point at which the conflict potential of alternative analogies could be suppressed.

Dual-Route Theories

Dual-route theories can also be modified to account for the present data. Patterson and Morton (1985) proposed further modifications to the standard Coltheart (1978) model; they suggested that the nonlexical route operates by means of orthography-to-phonology correspondence rules (OPCs) that deal with graphemes and word bodies (i.e., vowel + terminal-consonant segments of monosyllables that remain following the removal of the initial consonant or consonant cluster). They also stated that although "mappings at the grapheme level are simple one-to-one translations, the mapping rules for bodies are more complex and will sometimes require one-to-several translations" (p. 342). In the case of one-to-several rules, a plausible factor that might influence which one is applied (e.g., does -OVE → /əʊv/, /ʌv/, or /ʊv/?) is which rule has been used most recently. When there has been no recent use of a rule, it can be assumed that the system is biased toward the regular pronunciation for the word body (i.e., -OVE → /əʊv/).

With this type of model, the absence of consistency effects when subjects have not been preexposed to inconsistent words (Experiment 2) can be explained by assuming that the pronunciation is being produced by the system in its "normal" biased state. When preexposure of exception words occurs (Experiment 1), a temporary change in the biasing occurs, which gives more weight to the exception correspondence and a resultant delay in pronunciation and/or an irregularization error. When there is preexposure of an inconsistent word (Experiment 3), this serves to reinforce the normal bias toward the regular pronunciation and obviates any basis for a consistency effect.

This model also accounts for the nonword data of Experiments 1 and 3. In Experiment 1, the large number of irregularizations can be attributed to a temporary change in bias of the word body rules. As with the earlier account of analogy theory, the absence of consistency effects in terms of pronunciation latency can be attributed to the increased delay in pronunciation observed in Block 1; this delay ensured that pronunciation was initiated only after any conflict from alternative rules had been resolved. In Experiment 3, preexposure of inconsistent words ensured that the normal bias was maintained for those word bodies and thus that they could be pronounced as easily as consistent nonwords. The consistency effect for nonwords in Experiment 2, however, requires

further consideration. In Experiment 2, there was no preexposure, and, according to the above logic, the system should therefore have operated at its normal bias and provided no basis for a consistency effect. To account for this discrepancy, it is necessary to draw attention to a frequently overlooked logical point about dual-route theories. Within dual-route theory, it is often assumed that the pronunciation of nonwords is achieved solely by processes contained within the nonlexical route (e.g., Humphreys & Evett, 1985). This assumption presupposes that the system can establish a priori whether or not a letter string has a lexical address. Providing, as in the present experiments, that nonwords do not violate orthographic rules, there is no basis by which the system could achieve this. As a result, nonwords and words could be expected to engage both routes (Parkin, 1985). For inconsistent nonwords, this would result in the potential activation of lexical entries indicating spelling-to-sound correspondences differing from the normal bias of the nonlexical route. These would serve as a source of conflict and would delay pronunciation more than would consistent nonwords.

CONCLUSION

The present study showed that the consistency effect in word pronunciation occurs only under conditions in which subjects are first exposed to exception pronunciations. Because consistency effects for word pronunciation were perhaps the most interesting and provocative aspect of Glushko's (1979) original findings, it is disappointing that their occurrence is much more restricted. The results of the present experiments, along with those of Seidenberg et al. (1984), indicate that the pronunciation system is disrupted when subjects are systematically required to vary the manner in which word bodies are pronounced. However, because the nature of this manipulation is not widely reflected in the characteristics of normal text, the relevance of this phenomenon to the assembly of pronunciation in normal reading is seriously undermined.

At a theoretical level, both classes of model can be modified to account for the results. For analogy theory, this is achieved by accepting a distinction between spelling-to-sound information derived from the target lexical entry and other sources of information (Kay & Marcel, 1981). Dual-route theory is modified by proposing some flexibility in the correspondences specified in the nonlexical route and accepting that lexical analogies could affect the pronunciation of nonwords. Obviously these two theories have reached a point at which they are indistinguishable at an empirical level. The burden of proof may therefore have to come from other sources, most notably the study of acquired dyslexia. Alternatively, as Norris and Brown (1985) argued, this theoretical approach to the study of pronunciation knowledge may have outlived its usefulness. Nonetheless, the data reported here must be accommodated by any comprehensive approach to this problem.

REFERENCES

- ANDREWS, S. (1982). Phonological recoding: Is the regularity effect consistent? *Memory & Cognition*, **10**, 565-572.
- COLTHEART, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of human information processing*. London: Academic Press.
- GLUSHKO, R. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception & Performance*, **5**, 674-691.
- HENDERSON, L. (1985). Issues in the modelling of pronunciation assembly in normal reading. In K. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia*. London: Erlbaum.
- HORNBY, A. S. (1974). *Oxford advanced learner's dictionary of current English*. Oxford: Oxford University Press.
- HUMPHREYS, G. W., & EVETT, L. (1985). Are there independent lexical and nonlexical routes in word processing? An evaluation of the dual route theory of reading. *Behavioral & Brain Sciences*, **8**, 689-739.
- KAY, J., & MARCEL, A. (1981). One process, not two, in reading words aloud: Lexical analogies do the work of non-lexical rules. *Quarterly Journal of Experimental Psychology*, **33A**, 397-413.
- KUČERA, H., & FRANCIS, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.
- MADIGAN, S. W. (1969). Intraserial repetition and coding processes in free recall. *Journal of Verbal Learning & Verbal Behavior*, **8**, 828-835.
- MARCEL, A. J. (1980). Surface dyslexia and beginning reading: A revised hypothesis of the pronunciation of print and its impairments. In M. Coltheart, K. Patterson, & J. C. Marshall (Eds.), *Deep dyslexia*. London: Routledge and Kegan Paul.
- MCCLELLAND, J. L., & RUMELHART, D. E. (1982). An interactive activation model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review*, **89**, 60-94.
- MORTON, J., & PATTERSON, K. (1980). A new attempt at an interpretation, or, an attempt at a new interpretation. In M. Coltheart, K. Patterson, & J. C. Marshall (Eds.), *Deep dyslexia*. London: Routledge & Kegan Paul.
- NORRIS, D., & BROWN, G. (1985). Race models and analogy theories: A dead heat? Reply to Seidenberg. *Cognition*, **20**, 155-168.
- PARKIN, A. J. (1984). Redefining the regularity effect. *Memory & Cognition*, **12**, 287-292.
- PARKIN, A. J. (1985). Dual route theory and the consistency effect. *Behavioral & Brain Sciences*, **8**, 720-721.
- PATTERSON, K., & MORTON, J. (1985). From orthography to phonology: An attempt at an old interpretation. In K. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia*. London: Erlbaum.
- SEIDENBERG, M. S. (1985). Constraining models of word recognition. *Cognition*, **20**, 169-190.
- SEIDENBERG, M. S., WATERS, G. S., BARNES, M. A., & TANENHAUS, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning & Verbal Behavior*, **23**, 383-404.
- SHALLICE, T., WARRINGTON, E. K., & MCCARTHY, R. (1983). Reading without semantics. *Quarterly Journal of Experimental Psychology*, **35A**, 111-138.
- VENEZKY, R. L. (1970). *The structure of English orthography*. The Hague: Mouton.

NOTES

1. International Phonetic Alphabet, taken from Hornby (1974).
2. There has been a proliferation of terms used by different researchers for what are essentially the same types of items. For example, Patterson and Morton (1985) distinguished among nine and six types of words and nonwords, respectively. The present authors prefer the parsimony of Glushko's (1979) terminology and accordingly use it in this paper.
3. To avoid the problem of deciding whether or not an item had been given an irregular pronunciation, people with strong regional accents were not used. A person with a northern accent, for example, would generally pronounce GULL as /gʊl/ rather than /gal/.

APPENDIX A
Mean Pronunciation Latencies (in Milliseconds) of
Experimental Items Used in Experiments 1, 2, and 3

	Experiment 1		Experiment 2		Experiment 3	
	B1	B2	B1	B2	B1	B1
Consistent Words						
HILT	598	623	588	611	593	627
CUSP	582	557	559	566	583	621
DICE	579	583	530	616	566	604
TAIL	609	606	589	686	661	674
FEED	660	596	610	658	651	614
VERGE	627	626	645	640	639	658
COLD	668	560	567	569	575	585
HISS	679	583	596	588	599	571
COACH	613	621	567	632	642	653
WADE	609	584	570	612	614	656
POKE	627	597	569	619	626	639
LANE	562	579	576	607	589	573
FOAL	651	594	630	661	631	657
HIRE	640	624	568	626	604	606
MOON	578	579	624	559	662	638
GUST	587	580	610	532	581	581
RANK	549	558	623	517	570	590
BEND	601	597	654	596	628	610
GULP	630	610	622	568	595	621
SELL	601	576	656	564	605	600
MINK	562	552	632	551	611	606
MOLE	597	596	626	528	597	593
FOAM	660	622	695	617	690	719
LOOP	534	529	574	509	557	562
HUNK	592	573	592	585	595	629
BURN	592	596	686	589	644	621
SEEP	602	594	677	623	604	630
TREE	598	574	608	546	625	625
Inconsistent Words						
HINT	679	580	668	568	617	664
COVE	627	696	642	594	635	607
DOVE	589	613	625	596	595	606
tone	647	636	613	579	627	651
FEAR	698	665	707	649	688	677
VALVE	683	603	707	637	641	678
COST	605	572	624	561	591	618
HIVE	681	645	644	583	641	630
COUCH	675	657	647	581	643	680
WAVE	680	670	642	597	675	703
PERK	647	620	655	612	589	660
LEAF	545	568	599	545	558	586
FOWL	654	629	687	602	659	686
HERE	624	624	646	575	634	644
MOOD	603	660	592	607	614	659
GULL	634	577	581	593	571	579
ROSE	566	541	528	573	559	535
BASE	651	591	592	643	612	622
GUSH	613	629	594	647	606	662
SEAT	621	632	610	634	621	652
MILD	596	601	572	610	597	631
MOSS	575	604	561	602	567	614
FOOL	624	589	594	628	628	613
LOAD	624	570	537	577	575	560
HONK	643	596	585	586	577	595
BOOT	629	573	558	605	605	601
SOUR	668	605	598	648	622	592
TOWN	657	591	594	648	639	613

APPENDIX A (Continued)

	Experiment 1		Experiment 2		Experiment 3	
	B1	B2	B1	B2	B1	B1
Consistent Nonwords						
FILT	664	659	687	639	647	635
BUSP	621	620	675	556	653	610
BICE	738	673	638	606	661	595
YAIL	652	613	634	614	631	618
ZEED	634	618	664	568	619	666
BERGE	691	664	674	603	675	724
VOLD	628	633	679	605	656	625
NISS	608	652	612	548	576	618
NOACH	635	644	687	593	673	698
TADE	611	608	623	584	578	570
DOKE	632	600	641	586	667	638
NANE	631	624	664	587	639	617
LOAL	642	578	712	566	686	677
ZIRE	677	622	703	572	688	631
DOON	627	614	609	671	622	625
TUST	684	597	613	623	644	648
JANK	677	585	607	615	598	626
NEND	623	588	537	611	612	596
DULP	613	626	576	654	627	652
LELL	642	679	590	650	622	595
HINK	700	621	587	617	628	640
NOLE	703	564	556	587	623	650
BOAM	692	603	577	624	641	633
FOOP	732	668	650	671	692	694
LUNK	627	579	553	617	600	602
NURN	665	598	544	616	580	597
VEEP	735	624	654	662	627	670
KREE	655	632	589	631	657	640
Inconsistent Nonwords						
FINT	770	658	637	640	678	677
BOVE	651	595	585	657	641	610
BOME	726	705	596	695	648	655
YONE	635	633	597	651	691	627
ZEAR	736	598	633	687	663	665
BALVE	702	673	650	683	671	624
VOST	618	630	632	621	621	589
NIVE	613	620	549	635	599	600
NOUCH	712	607	632	643	652	646
TAVE	643	623	614	676	652	683
DERK	692	629	595	663	632	619
NEAF	670	696	567	654	626	630
LOWL	648	626	586	649	617	609
ZERE	628	612	652	728	641	620
DOOD	677	646	717	589	629	651
TULL	628	608	669	608	614	648
JOSE	648	672	706	630	644	693
NASE	648	636	682	568	658	663
DUSH	590	600	672	565	593	628
LEAT	607	564	640	548	596	626
HILD	645	647	664	606	633	676
NOSS	553	569	627	567	598	650
BOOL	645	677	683	629	697	677
FOAD	696	664	689	639	713	680
LONK	615	561	588	562	623	603
NOOT	627	614	684	552	637	667
VOUR	640	656	700	610	675	672
KOWN	638	646	709	670	637	713

APPENDIX B

List of Items Used in the Initial Processing Phase of Experiments 1, 2, and 3

Experiment 1		Experiment 2		Experiment 3	
W	NW	W	NW	W	NW
PINT	YINT	DEAL*		MINT	RINT
DOVE	FOVE	DUMP	FUMP	WOVE	GOVE
COME	POME	WEST	DEST	HOME	JOME
DONE	JONE	BEAM	KEAM	CONE	PONE
BEAR	KEAR	HATE	JATE	NEAR	PLEAR
HALVE	FALVE	HITCH	FITCH	SALVE	DALVE
HOST	JOST	CAME	PAME	LOST	FOST
GIVE	BIVE	BELT	GELT	FIVE	KIVE
TOUCH	DOUCH	PILL	YILL	POUCH	BOUCH
HAVE	JAVE	DUCK	HUCK	GAVE	BAVE
CLERK	BLERK	MIST	NIST	JERK	NERK
DEAF	HEAF	BLUE	PLUE	SHEAF	CREAF
BOWL	GOWL	TEACH	NEACH	GROWL	DROWL
WERE	DERE	GRIP	BRIP	MERE	FLERE
HOOD	SOOD	HURT	JURT	FOOD	VOOD
BULL	JULL	CLICK	BLICK	DULL	RULL
DOSE	KOSE	PREY	KREY	POSE	VOSE
VASE	YASE	PINE	JINE	CASE	DASE
PUSH	JUSH	HEAL*		RUSH	FUSH
SWEAT	PREAT	VENT	YENT	BEAT	DEAT
GILD	PILD	HIKE	SIKE	CHILD	PRILD
GROSS	FROSS	SIGH	VIGH	LOSS	FOSS
WOOL	MOOL	MOPE	YOPE	POOL	NOOL
BROAD	TROAD	BRIEF	TRIEF	ROAD	DOAD
MONK	NONK	DUSK	KUSK	PLONK	BRONK
SOOT	WOOT	SWING	PRING	ROOT	DOOT
POUR	KOUR	BITE	JITE	FLOUR	PLOUR
MOWN	YOWN	GRACE	FRACE	DOWN	JOWN
		SHACK	FRACK		
		WIPE	MIPE		
		GARB	PARB		

Note: W = word; NW = nonword. *Due to an oversight, DEAL and HEAL were both included as items in Experiment 2. There were also 31 words and 29 nonwords in this phase, rather than 28 for each as in the other experiments. However, since these were not the experimental items for which pronunciation latencies were measured, this was not considered a serious problem.

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