On the control of visual word recognition: Changing routes versus changing deadlines

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Two different accounts have been proposed to explain the fact that (1) an effect of word frequency is present when readers of transparent orthographies read only words aloud and (2) the effect of word frequency is eliminated when subjects name words and nonwords mixed together in a single block. In the route-shifting account, subjects shift from using a lexical route that can read only words to using a nonlexical route that can read both words and nonwords via the use of sublexical spelling-sound correspondences (hence, no word frequency effect). The essence of the second, time criterion account is that the elimination of the word frequency effect is determined by the speed with which the nonwords are processed, because subjects attempt to homogenize the point in time at which they release an articulation. These two different accounts are pitted against each other in a series of naming experiments utilizing the transparent Turkish orthography. A word frequency effect persists even when words and nonwords are mixed together, provided that nonword sets are matched so as to be named as quickly as the high-frequency words and as slowly as the low-frequency words, respectively. This result is argued to be consistent with the time criterion account, but not with the unadorned route-shifting account.

The question of how skilled readers generate the pronunciations of written words has been the topic of considerable research over the last 3 decades. One framework assumes that alphabetic orthographies afford two distinct ways of converting print to sound in the absence of semantic involvement (e.g., Baluch & Besner, 1991; Besner, 1999; Besner & Smith, 1992; Carr & Pollatsek, 1985; Coltheart, 1980; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). The lexical route consists of an orthographic word level in which each node represents a word known to the reader (i.e., has localist representations). Presentation of a word results in cascaded activation across feature, letter, and word levels, which spreads to (*addresses*) whole-word nodes in the phonological output lexicon and, from there, to the phonemic buffer and overt speech (see Figure 1).

The nonlexical route translates print into a phonological code via the *assembly* of sublexical spelling-sound correspondences. The exact nature of these correspondences is a matter of some debate and need not detain us here, beyond the comment that grain size appears to vary across orthographies in a systematic way that depends on

how consistent the spelling-sound correspondences are (Ziegler, Perry, Jacobs, & Braun, 2001). The output of this process activates the phonemic buffer and then speech. The two routes (*addressed* and *assembled*) can operate concurrently, but they do not typically finish at the same time, because different factors selectively affect their operations. For example, word frequency affects the addressed pathway, but not the assembled pathway (e.g., Baluch & Besner, 1991; McCann & Besner, 1987), whereas letter length affects the assembled route but not the lexical route (at least for monosyllabic words; Weekes, 1997).

One question that has been investigated in the context of this framework concerns whether it is possible to exert control over which route is utilized to read aloud and, if so, what contextual factors play a role. For example, it is well known that high-frequency words can be named more quickly than low-frequency words in *opaque* orthographies, such as English (see Monsell, 1991, for a review). This is also true in *transparent* orthographies, such as Italian (Tabossi & Laghi, 1992), Turkish (Raman, Baluch, & Sneddon, 1996), and Dutch (Hudson & Bergman, 1985), and for mixed scripts, such as Persian (Baluch & Besner, 1991), in which the presence/absence of diacritics signals whether the word can be read by application of sublexical spelling-sound correspondence knowledge or whether lexical retrieval is necessary.

Critically, several reports have indicated that this word frequency effect is eliminated when words and nonwords are mixed together in a single block (e.g., Baluch & Besner, 1991; Hudson & Bergman, 1985; Raman et al., 1996;

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Figure 1. Dual-route model of naming. From "Basic Processes in Reading: Multiple Routines in Localist and Connectionist Models," by D. Besner. In P. A. McMullen and R. M. Klein (Eds.), *Converging Methods for Understanding Reading and Dyslexia*, 1999, Cambridge, MA: MIT Press. Copyright 1999 by MIT Press. Adapted with permission.

Simpson & Kang, 1994). Within the dual-route framework sketched above, the elimination of the word frequency effect can be interpreted as evidence that the presence of nonwords results in reading aloud's being accomplished by shifting from the lexical route to the nonlexical route. Nonwords do not have a lexical entry in the orthographic lexicon, and therefore, they cannot be read via the lexical route. The only way nonwords can be read is by employing sublexical print-to-sound translation rules via the nonlexical route. Since *words* in transparent orthographies can also be correctly read via the nonlexical route, it is assumed that readers now use the nonlexical route to read both the words and the nonwords (Baluch & Besner, 1991; Raman et al., 1996; Simpson & Kang, 1994; Tabossi & Laghi, 1992).

One of the wider implications of such a claim is that the operations of the two routes may, to a large extent, be independent of one another. This is because, at least in principle, it is possible for the reader to completely ignore or shut down the operation of one route in favor of the other when deriving phonology from print. Moreover, the naming of nonwords under mixed conditions should be speeded up, because readers make primary use of the nonlexical route. According to Paap and Noel

(1991), the lexical route is assumed to be unresponsive and unyielding to mixed-list effects (i.e., to strategic factors), due to its automated nature, whereas the nonlexical route is strategically tuned in response to items in the list.

However, there is one problem with the change-of-routes explanation when it is applied to transparent orthographies: Words are still reported to be named significantly more quickly than nonwords, despite the fact that the word frequency effect disappears for the same words. If readers of transparent orthographies change routes in response to the presence of nonwords, how could the nonlexical route generate shorter response times (RTs) for words than for matched nonwords? Moreover, can the lexical route be totally abandoned by readers of (irregular) English in a manner similar to that for readers of Persian (Baluch & Besner, 1991) and Italian (Tabossi & Laghi, 1992)? Recently, Zevin and Balota (2000) summarized the evidence from transparent orthographies as "more powerful demonstrations of attentional control" (p. 121). This is not surprising; contrary to what is the case for readers of mixed or opaque writing systems, who need to employ appropriate strategies for successful reading at all times, readers of completely transparent orthographies are not exposed to linguistic dichotomies

and, thus, are not accustomed to employing different strategies in their natural reading environment. Therefore, the impact of responding to a mixed list of items with an appropriate strategy is expected to be greater for readers of transparent orthographies than for readers of opaque orthographies.

It is, thus, not the case that the *changing routes* account has gone unchallenged, nor is it the case that there is a general consensus regarding the extent to which the switch between the routes takes place. At least two views have been implicitly put forward: an all-or-none route-switching account (e.g., Baluch & Besner, 1991; Raman et al., 1996; Tabossi & Laghi, 1992) and an attenuation account (e.g., Monsell, Patterson, Graham, Hughes, & Milroy, 1992; Paap & Noel, 1991). A related question is whether attenuation could be a function of orthographic transparency and/or a list composition effect, with all-or-none (i.e., complete abandonment of one route in favor of the other) as one extreme and attenuation (i.e., some reliance on the other route) as another. It is noteworthy that a number of authors have appealed to the attenuation idea to explain their findings. Paap and Noel reported that subjects were faster and more accurate when the list consisted of irregular words only than when regular words were added to the list. They argued that when naming irregular words only, readers make prime use of the highly automated lexical route, which is faster than the nonlexical route (assumed to be involved in the naming of regular words). However, when both regular and irregular words are mixed together, this prompts the operation of both routes, which in turn may slow the naming of irregular words, since their pronunciation is delayed for the (incorrect) outcomes of the nonlexical route to become available to the reader. This interpretation suggests that the operations of the two routes are not independent of each other; rather, a checking mechanism must be involved prior to articulation. Lupker, Brown, and Colombo (1997) suggested that readers employ a lexical checking strategy when generating phonology for words, to ensure that a corresponding phonological code exists in the phonological output lexicon. It is noteworthy that this mechanism is assumed to be orthogonal to the nature of the processing of the lexical and the nonlexical routes and is viewed as an additional strategy for ensuring successful articulation. Moreover, a checking mechanism is not viable when naming nonwords only, because there are no representations in the phonological output lexicon for nonwords.

In a further manipulation of regularity in English, Monsell et al. (1992) presented readers with irregular words or with irregular words mixed with an equal number of nonword fillers. This list composition manipulation was argued to provide conditions under which the use of both the lexical route (for irregular word naming) and the nonlexical route (for nonword naming) was maximized. Monsell et al. found that high-frequency irregular words were named more quickly and more accurately in pure blocks than when they were presented with nonwords. In brief, the main conclusion drawn from the re-

sults of Monsell et al. and Paap and Noel (1991) was that readers of English could exercise strategic control over the use of the nonlexical route. Even if some of the earlier findings reported on English may be attributed to "weaknesses" in experimental manipulations or the mixed nature of English spelling, the results of strategic control over the use of lexical and nonlexical routes in transparent scripts, in response to the effects of nonword fillers, may also be questioned insofar as a complete shutoff of the lexical route is concerned. In almost all the studies on transparent writing systems—namely, Persian (Baluch & Besner, 1991), Serbo-Croatian (Katz & Feldman, 1983), and Turkish (Raman et al., 1996)—words were named significantly more quickly than nonwords despite the elimination of the frequency or the semantic priming effect for the same words when they were mixed with nonwords. So what makes it possible for words to be named via a nonlexical route (hence, no frequency and semantic priming effect) and yet to produce faster naming, as compared with nonwords? In short, a different explanation may be needed for the effects of nonword fillers on single-word naming.

An alternative explanation has been offered by Lupker et al. (1997), who set out to replicate Monsell et al.'s (1992) experiments. Lupker et al. reported that low-frequency regular words took longer to name when mixed with low-frequency irregular words than when they were presented on their own—that is, in a pure block. According to the route-changing position, when low-frequency regular words are presented on their own, they can be named via the nonlexical route. However, the nonlexical route fails in the presence of irregular words, leading to the deemphasis or the turning down of the nonlexical route—hence, the slower naming of regular words in mixed blocks. Lupker et al. argued that "there would appear to be no obvious reason within the dual-route framework for observing a mixed-block RT advantage with any type of stimuli. Presumably, blocks that contain only one type of stimulus present the optimal opportunity for readers to balance their reliance on the two routes in a way that produces the shortest possible naming latencies. Assuming that readers can adopt strategies of this nature, introducing a second type of stimulus into those blocks can only upset that balance, which should lead to longer naming latencies in the mixed-block conditions (rather than speed it up). Thus these particular results do not lend themselves to an explanation in terms of a de-emphasis of routes" (p. 575).

Lupker et al. (1997) subsequently proposed the time criterion account to explain the nature of strategy effects in naming. The proposition is that there exists a time criterion factor determined by the perceived difficulty of the stimuli that are to be named, prior to articulation. The notion of difficulty is central to the time criterion account because it leads to strategically adjusting the generation of an acceptable criterion appropriate for all the stimuli to be named. That is, naming RTs vary in response not just to the individual characteristics of a stimulus, but also to how easy or difficult it is to name other, preced-

ing stimuli that are mixed together in the same block. A time criterion for naming all the items in the block is subsequently set. This effect, as summarized by Rastle and Coltheart (1999), is “simply put, when fast things are mixed with slow things, those fast things slow down; when slow things are mixed with fast things, those slow things speed up” (p. 494) and, in effect, leads to the homogenization of RTs. That is not to say that subjects will always respond at that precise moment in time in naming all the stimuli. If that were the case, one would not observe a mean difference between different types of stimuli mixed in a block (e.g., high- and low-frequency words, as in Raman et al., 1996, Experiment 1). The implication of mean differences observed in a mixed block is that subjects do generate a response sometimes sooner and sometimes later than the set time criterion—that is, in response to easier than average and more difficult than average items, respectively. The emerging viewpoint here is that the homogenization of RTs can be either absolute or partial. In view of the evidence to date, we take the position that homogenization is *absolute* if there is no mean difference between the types of stimuli in a mixed block (e.g., high-frequency words, low-frequency words, or nonwords) and *partial* if a mean difference is reported (e.g., high- and low-frequency words). What determines the extent of homogenization of RTs is the overall difficulty of the items in a given block. Further evidence in this vein has recently been documented in a series of articles by Lupker and colleagues (e.g., Chateau & Lupker, 2003; Kinoshita & Lupker, 2002; Taylor & Lupker, 2001).

One major concern here is the difficulty in distinguishing between the attenuation and the time criterion accounts, as opposed to the all-or-none route-shifting and the time criterion accounts. When words are mixed with nonwords, three outcomes are possible: (1) According to the route-shifting account, the word frequency effect should be eliminated regardless of the difficulty of the nonwords; (2) according to the time criterion account, the word frequency effect will be determined by the difficulty of nonwords in the list; and (3) according to the attenuation account, the word frequency effect is not necessarily eliminated but is reduced in the presence of nonwords, even if they are made as easy to read as words. In this respect, the time criterion account provides a way of explaining the typical elimination of the word frequency effect that is different from that of the route-shifting account in the experiments in which words are mixed with nonwords, such as those reported by Baluch and Besner (1991), Hudson and Bergman (1985), and Raman et al. (1996). In all these studies, the nonwords were named more slowly than the words, although the word frequency effect had disappeared. The time criterion account would predict this effect, because the nonwords were considerably more difficult to name than the words; thus, the articulation point would be placed beyond the range that yields a frequency effect.

It is also noteworthy that the contribution from the lexical route to word naming varies across transparent

orthographies, due to such factors as stress assignment (e.g., Serbo-Croatian) and some irregularity in print-to-sound translation (e.g., Italian). It follows that readers of orthographies for which lexical information is crucial in determining the correct response become more *strategic* by necessity during the course of reading development than do readers of extremely transparent orthographies. For example, when English is read, the claim is that nonwords can be read only by the nonlexical route and irregular words such as *pint* can be read only by the nonlexical route (see, e.g., Coltheart et al., 2001). In very transparent orthographies, however, the nonlexical route can be used to read both words and nonwords.

An extreme case of a transparent orthography is Turkish, which is characterized by totally transparent feed-forward and feed-back (bidirectional) representations between orthography and phonology that are also context independent. That is, mappings both from spelling to sound and from sound to spelling are one to one and completely consistent. Unlike readers of English and other alphabetic writing systems that impose strategies to be adopted early on in reading development, because of irregular and/or context-dependent representations and stress assignments, Turkish readers are not faced with such impositions. Therefore, in Turkish, word naming can be just as successful whether one is primarily using the lexical or the nonlexical route. That is not to say that reading by skilled Turkish readers is primarily nonlexical. On the contrary, Raman et al. (1996) reported a robust 52-msec word frequency effect when only words were presented for naming. It was concluded that skilled readers must use the lexical route for naming, given the observation of a word frequency effect. This 52-msec effect was reduced to 3 msec in a second experiment when the same words were presented together with an equal number of nonwords that matched the words on initial letter and number of letters and syllables. In Turkish, when high- and low-frequency words and nonwords are all mixed together in a single block, as in Raman et al.'s second experiment, the composition of stimuli favors a shift to the use of the nonlexical route because the nonwords can be named only via the nonlexical route and this same route can also name all the words correctly. Raman et al.'s (1996) results are comparable to those reported for transparent Persian, in that Baluch and Besner (1991) reported a 35-msec word frequency effect that reduced to 11 msec when the words were mixed with nonwords.

Furthermore, there are no sources of irregularity in Turkish and, hence, no conflicting outcomes between the lexical and the nonlexical routes. Under such conditions, it is possible that readers of Turkish, unlike readers of English, do not require the simultaneous activation of both the lexical and the nonlexical routes to generate phonology. Therefore, one question is whether *skilled* readers of Turkish *ever* adopt word-reading strategies in response to different list compositions. This question is reevaluated in the present study.

In contrast to the influence of word frequency on the lexical route, Weekes (1997) reported that increasing the

number of letters affects naming time to nonwords, not words, once the number of orthographic neighbors is partialled out. Therefore, nonword naming RTs can be manipulated by varying letter length to create a set of "fast" and "slow" nonwords. We can thus manipulate perceived difficulty in Turkish by manipulating letter length, a key feature of the time criterion account.

The route-shifting account makes a clear prediction. If readers rely on the lexical route to read Turkish words when only words are presented but shift to the nonlexical route when words and nonwords are mixed together, the perceived difficulty of the nonwords should not matter. All that matters is that the presence of the nonwords promotes a shift from using the lexical route to using the nonlexical route to name *all* stimuli, since nonwords can be read only by the nonlexical route. In particular, for reasons discussed above and in line with evidence from transparent orthographies, the extent of this shift for Turkish readers is predicted to be absolute—that is, a complete shift to using only the nonlexical route. Consequently, the word frequency effect should be eliminated.

The time criterion account also makes a clear and different prediction from that of the route-shifting account. In the criterion account, it is the time to name nonwords that is critical, because the central idea is that the point in time at which a naming response begins is homogenized as a function of the items in the list. That is, if nonwords are made as easy as words to name by manipulating letter length, the word frequency effect should persist. These contrasting predictions were put to the test in a series of four naming experiments.

Experiment 1 validated that the two sets of nonwords we created will be named as quickly as a set of high- and low-frequency words (respectively) under blocked conditions. These two sets of nonwords were then utilized to examine whether an articulation point that was appropriate to the perceived difficulty in pronouncing the high- and low-frequency words would be maintained.

If both the time criterion account and the changing routes account offer viable explanations for the elimination of the word frequency effect when words are mixed with nonwords, which account (if the two accounts are mutually exclusive) should be preferred? The time criterion account is, of course, mute with respect to the issue of how many routes there are and which route actually drives pronunciation. The purpose of the present study was twofold: first, to reexamine the earlier account from Turkish in view of the time criterion account and, second, to shed light on the controversy, given the straightforward predictions for Turkish, which is ultimately a "purer" orthography and, thus, an ideal orthographic medium with which to test the claims of the two accounts, as compared with English.

EXPERIMENT 1

The aim of Experiment 1 was to ensure two things: first, that the selected set of high- and low-frequency words would produce a significant difference in naming

time and, second, that one set of nonwords would be named as quickly as the high-frequency words and another set as slowly as the low-frequency words.

Method

Subjects. The subjects were eight adult native readers of Turkish, who were undergraduates at Eastern Mediterranean University. Each subject received course credit for participating in the experiment.

Materials. Word frequency counts were obtained for 200 words, compiled from books and daily newspapers, on the basis of subjective ratings from 60 highly literate, native speakers of Turkish (see the Appendix). A 7-point rating scale ranging from 1 (*most frequent*) to 7 (*least frequent*) was used (Gernsbacher, 1984; Gordon, 1985). Subjective ratings, rather than objective word frequency counts, were used because no current objective count exists for Turkish. A word was classified as high frequency if its rating was a maximum of 2 and as low frequency if its rating was a minimum of 6. Two sets of 20 words (one high frequency and one low frequency) were selected. These items were mono- or bisyllabic and were matched on initial phonemes and number of letters. It should be noted that none of these items belong to the set used in Raman et al. (1996).

Two sets of pronounceable nonwords were also created using print-to-sound translation rules of Turkish. Creating two sets of nonwords that differed in naming time was accomplished by varying the number of letters, since letter length affects nonword naming time (Weekes, 1997). Pilot work with undergraduate students at Eastern Mediterranean University, using pure blocks of words, and nonwords that varied in length between blocks, was carried out in order to select a set of nonwords that matched the naming times for the high- and the low-frequency words, respectively. Nonwords that could be named as quickly as high-frequency words were three letters long, whereas nonwords that took as long to name as low-frequency words were four and five letters long. This resulted in two sets of nonwords, with 20 items in each set.

The experimental trials consisted of four pure blocks: (1) 20 nonwords speed matched to the high-frequency words, (2) 20 nonwords speed matched to the low-frequency words, (3) the set of 20 high-frequency words, and (4) the set of 20 low-frequency words. Order of presentation of blocks across subjects was counterbalanced using a Latin-square design. Each test block was preceded by 10 practice trials appropriate for that block.

Apparatus and Procedure. An Amstrad PC7-486 computer was used to control the presentation of the stimuli. The program was written in Visual Basic for DOS. A voice-activated key worn around the neck detected the onset of articulation. RTs were timed from the onset of the stimulus to the onset of articulation.

Each subject was seated approximately 70 cm from the screen and was instructed, both verbally and in writing, to pronounce the stimulus presented on the screen as quickly and as accurately as possible. The stimuli were displayed in black on a gray background in 16 point Times New Roman and appeared in the middle of the display screen. The subjects were told that some of the stimuli would consist of letter strings that they had never encountered before. The stimulus disappeared from the screen as soon as articulation began. A 2-sec blank period intervened between trials.

An initial set of 10 practice trials was run to ensure that the voice key level was adjusted appropriately and the subject was accustomed to the procedure. Each subject then received a different random order of items within both practice and test trials, for a total of 120 trials across the four blocks.

Results

The mean RTs and associated percentages of errors for each condition can be seen in Table 1. Planned comparisons revealed that the 57-msec difference between the

Table 1
Mean Response Times (RTs, in Milliseconds), Standard Deviations (SDs), and Percentages of Errors to Words and Nonwords in the Four Pure-Block Conditions (High-Frequency Words, Low-Frequency Words, Short Nonwords, and Long Nonwords) in Experiment 1

Stimulus Type	RT	SD	% Errors
1. High-frequency words	636	49	1.0
2. Matched nonwords	626	73	3.4
<i>Difference</i>	10		-2.4
3. Low-frequency words	693	41	1.8
4. Matched nonwords	695	81	3.7
<i>Difference</i>	-2		-1.7
Nonword effect	69		0.3
Word frequency effect	57		0.8

naming of high- and low-frequency words was significant [$t_s(7) = 9.67$, $SEM = 5.92$, $p < .001$; $t_i(38) = 2.02$, $SEM = 29.69$, $p < .05$]. There was no significant difference between the naming of high-frequency words and their matched nonwords [$t_s(7) = 0.61$, $SEM = 15.86$, $p = .55$; $t_i(38) = 0.44$, $SEM = 22.30$, $p = .66$] and no significant difference between the naming of low-frequency words and their matched nonwords [$t_s(7) = 0.08$, $SEM = 19.77$, $p = .94$; $t_i(38) = 0.10$, $SEM = 26.89$, $p = .95$]. There were no significant error effects.

EXPERIMENT 2

The results of Experiment 1 confirmed that (1) one of the nonword sets was speed matched to the high-frequency words and the other nonword set was speed matched to the low-frequency words and (2) there was a substantial word frequency effect. Armed with these sets, we then turned to Experiment 2. Here, two mixed blocks were created: one in which high-frequency words were mixed with their speed-matched nonwords and another in which low-frequency words were mixed with their speed-matched nonwords. The changing routes account predicted that the word frequency effect would be eliminated, because the presence of nonwords would induce subjects to shift from using the lexical route to read the words to using the nonlexical route to read both the words and the nonwords (Baluch & Besner, 1991; Raman et al., 1996). The time criterion account, however, would allow for a word frequency effect, because the subjects would be encouraged to pick and maintain an articulation point that was consistently midway between the perceived difficulty in pronouncing the word and the nonword stimuli in each block.

Method

Subjects. Fifteen adult native readers of Turkish, who were undergraduates at Eastern Mediterranean University, participated in the experiment. Each subject received course credit for his/her participation. The subjects were drawn from the same student population as that in Experiment 1.

Materials, Apparatus, and Procedure. The materials and apparatus were the same as those in Experiment 1. Stimulus presentation was blocked. In one block, 20 high-frequency words were

randomly mixed with their 20 speed-matched nonwords. In another block, the 20 low-frequency words were mixed with their 20 speed-matched nonwords. Each of the two blocks of test trials was preceded by an appropriate practice block that consisted of 20 items (10 words and their speed-matched nonwords) also used in Experiment 1. Block order was again counterbalanced.

Results and Discussion

The mean RTs and associated percentages of errors for each condition can be seen in Table 2. The 38-msec difference between high- and low-frequency words was significant [$t_s(14) = 2.72$, $SEM = 14.22$, $p < .017$; $t_i(38) = 2.05$, $SEM = 20.02$, $p < .04$]. There was no difference between high-frequency words and their speed-matched nonwords [$t_s(14) = 0.58$, $SEM = 25.62$, $p = .57$; $t_i(38) = 0.65$, $SEM = 24.08$, $p = .51$] or between low-frequency words and their speed-matched nonwords [$t_s(14) = 0.31$, $SEM = 25.96$, $p = .76$; $t_i(38) = 0.4$, $SEM = 25.59$, $p = .71$]. Again, there were no significant error effects.

The persistence of a word frequency effect in the presence of speed-matched nonwords is taken as evidence that it is not the mere presence of nonwords but the speed with which they are named that has an impact on word naming. This finding is contrary to the predictions of the all-or-none shift account but is in line with the predictions of the time criterion account. That is, the presence of a frequency effect is evidence that the lexical route has not been abandoned but is operating in parallel to the nonlexical route (since subjects are also able to articulate nonwords). It is noteworthy that a word frequency effect in the presence of speed-matched nonwords is also predicted by the attenuation account. What is not predicted by the attenuation or the route-shifting account, however, is the reduction of not just the word frequency effect between Experiments 1 and 2 from 57 to 38 msec (19 msec), but also the 24-msec reduction in effect size for nonwords from 69 to 45 msec. Crucially, the reduction in the nonword effect is comparable to the reduction in the size of word frequency effect and lends further support to the time criterion explanation. That is, it is not the status of the word or the nonwords but the speed with which stimuli are named that matters.

Table 2
Mean Response Times (RTs, in Milliseconds), Standard Deviations (SDs), and Percentages of Errors to Words and Nonwords in the Two Mixed-Block Conditions (High-Frequency Words and Their Speed-Matched Nonwords and Low-Frequency Words and Their Speed-Matched Nonwords) in Experiment 2

Stimulus Type	RT	SD	% Errors
1. High-frequency words	688	67	1.3
2. Matched nonwords	673	85	3.1
<i>Difference</i>	15		-1.8
3. Low-frequency words	726	81	3.2
4. Matched nonwords	718	82	3.0
<i>Difference</i>	8		0.2
Nonword effect	45		0.1
Word frequency effect	38		1.9

Methodological Considerations

The general consensus is that when faced with the naming of stimuli in pure blocks, subjects employ the most appropriate and optimal strategy accordingly. For example, when words are of one type only (pure block), RTs are reported to be shorter than when two types of words are mixed (mixed block). Frederiksen and Kroll (1976) demonstrated that subjects were significantly faster in naming high-frequency words when they were in pure blocks than when they were mixed with low-frequency words. Arguably, one reason to suspect that mixed-block (two types of stimuli) and mixed (all four types of stimuli) presentations exert differential effects on RTs is that disturbing the composition of the stimuli in the set may encourage lexical, as opposed to nonlexical, reading. Presumably, when words (high and low frequency) and nonwords are mixed in a single block, there is a 75% tendency to use the nonlexical route (for low-frequency words and nonwords); however, when high-frequency words are mixed with nonwords, there is a 50% tendency to name words by using the nonlexical route (for nonwords), and there is a 100% tendency to name all the stimuli by using the nonlexical route when low-frequency words are mixed with nonword fillers. Such manipulations might affect the position of the time criterion and, consequently, the magnitude of the word frequency effect. The rationale for Experiments 3 and 4 takes these considerations into account.

EXPERIMENT 3

The aim of Experiment 3 was to address the methodological issue of mixed-block design (i.e., two blocks, each block containing either high- or low-frequency words and their speed-matched nonwords) versus an all-mixed design (i.e., a single block consisting of high- and low-frequency words and their speed-matched nonwords) and, thus, to further investigate the impact of blocking, to ensure that the result of Experiment 2 was not an artifact of the experimental design.

Two predictions were made here. Again, the changing routes account predicts that the word frequency effect should be eliminated, because the presence of nonwords would induce subjects to shift from using the lexical route to read the words to using the nonlexical route to read both the words and the nonwords. In contrast, the time criterion account would predict that the word frequency effect should persist, since the subjects would use an articulation point that was midway between the "fast" and the "slow" items, and that the word frequency effect should be slightly smaller than that in Experiment 2, since all four types of stimuli would now be mixed.

Method

Subjects. Fifteen adult native readers of Turkish, who were undergraduates at Eastern Mediterranean University, participated in this experiment. Each subject received course credit for his/her participation. The subjects were drawn from the same student population as that in Experiment 1.

Materials, Apparatus, and Procedure. The materials and apparatus were the same as those in Experiment 1. The order of stimulus presentation was randomized for both the practice and the test blocks, and each subject received a different random order of stimuli. All word and nonword stimuli used as test trials in Experiment 1 were mixed together in a single block of 80 items in Experiment 3 that was preceded by a practice block of the same 40 items as those used as practice in Experiment 1.

Results and Discussion

The mean RTs and associated percentages of errors for each condition can be seen in Table 3. Planned comparisons showed that high-frequency words are named 26 msec more quickly than low-frequency words [$t_s(14) = 3.18$, $SEM = 8.59$, $p < .001$; $t_t(38) = 2.04$, $SEM = 12.98$, $p < .05$]. There was no difference between high-frequency words and their speed-matched nonwords [$t_s(14) = 1.39$, $SEM = 9.14$, $p = .19$; $t_t(38) = 0.83$, $SEM = 15.46$, $p = .40$] or between low-frequency words and their speed-matched nonwords [$t_s(14) = 0.43$, $SEM = 9.80$, $p = .65$; $t_t(38) = 0.34$, $SEM = 13.42$, $p = .73$]. There were no significant error effects.

The results from Experiment 3 are clear. Mixing all words with their speed-matched nonwords together in a single block does not eliminate the word frequency effect. The similarity of these results to those observed in Experiment 2 were confirmed by a cross-experiment analysis of variance (ANOVA). This yielded a main effect for frequency [$F(1,28) = 15.43$, $MS_e = 1,044.09$, $p < .001$]. There was no main effect for block type ($F < 1$) and no interaction ($F < 1$).

We make two claims here. First, the empirical claim is that the word frequency effect across Experiments 2 and 3 is not an artifact of experimental manipulation—that is, mixed-block versus all mixed. Second, the theoretical claim is that the route-shifting account, in its current form, has no explanation for the word frequency effect when words are mixed with nonwords in one block, since the claim is that the shift from lexical to nonlexical reading aloud is categorical and dictated by the presence of nonwords in the list. This account predicts that the word frequency effect should have been eliminated, as it was in previous experiments in which the nonwords were not

Table 3
Mean Response Times (RTs, in Milliseconds), Standard Deviations (SDs), and Percentages of Errors to Words and Nonwords in the All-Mixed Condition (High- and Low-Frequency Words and Their Speed-Matched Nonwords) in Experiment 3

Stimulus Type	RT	SD	% Errors
1. High-frequency words	693	78	1.0
2. Matched nonwords	679	63	1.5
Difference	14		-0.5
3. Low-frequency words	719	64	2.1
4. Matched nonwords	723	53	2.3
Difference	-4		-0.2
Nonword effect	44		0.6
Word frequency effect	26		1.1

speed matched with the words (e.g., Baluch & Besner, 1991; Raman et al., 1996). In contrast, the time criterion account is consistent with (1) the observation that the word frequency effect is eliminated when nonwords that are not speed matched to the words are mixed with words (Baluch & Besner, 1991; Hudson & Bergman, 1985; Raman et al., 1996), as well as (2) the observation that a word frequency effect persists provided that nonwords are speed matched to the words.

When nonwords are named more slowly than both high- and low-frequency words because they are matched for length (as in Baluch & Besner, 1991; Hudson & Bergman, 1985; Raman et al., 1996), a null effect for word frequency is observed, because readers set the criterion for articulation beyond one that would produce a lexicality effect. It is noteworthy that words are still named more quickly than nonwords but there is no word frequency effect, exactly as Baluch and Besner (1991), Hudson and Bergman (1985), and Raman et al. (1996, Experiment 2) reported. However, when nonwords are selected that are speed matched to the high- and low-frequency words, as in the present study, a word frequency effect should be obtained regardless of type of blocking. Nonetheless, since type of blocking has an impact on the predictability of items in the naming list, the size of word frequency is expected to vary in proportion to where the criterion is placed. That is, where readers can reliably predict that all the items in the block are words, the criterion will be partially homogenized to accommodate the naming of both high- and low-frequency words. Similarly, if all the items in the list can be predicted to consist of nonwords, a midpoint between slow and fast items will be set for naming; thus, an effect for nonwords similar to that of the word frequency effect should be observed when words and nonwords matched on naming speed are presented in separate blocks.

EXPERIMENT 4

Experiment 4 was designed to firmly establish and consolidate the extent to which the present results clearly distinguish between the time criterion and the attenuation accounts. The aim was to contrast the size of the word frequency effect in Experiment 3 (in which words and nonwords were all mixed randomly) with a condition in which high-frequency and low-frequency words were mixed together in a single block that did not contain the nonwords. Nonwords speed matched to high- and low-frequency words were presented in another block for naming.

Again, two predictions were made. The time criterion account predicted a word frequency effect that would be similar in magnitude to the one observed in Experiment 3. This is because the time criterion ought to homogenize at a similar point across Experiments 3 and 4 to name the same words (high- and low-frequency words) irrespective of whether their speed-matched nonwords were present or absent. Moreover, the extent of homogeniza-

tion of nonword RTs would be predicted to mimic the homogenization of word RTs, since nonwords match words on naming speed. That is, a comparable magnitude for word frequency and nonword effect would be predicted. In contrast, the attenuation account predicted that when only words were presented, the magnitude of the frequency effect would be greater than when words were mixed with nonwords, because when presented just with words, readers would be expected to read *only* via the lexical route, which is highly sensitive to frequency, thus yielding an exaggerated word frequency effect in Experiment 4, as compared with Experiment 3. One cannot generate a viable prediction on the basis of the attenuation account, because nonwords can be named only using the nonlexical route, whereby any difference in nonword naming RTs can be attributed to a length effect (Weekes, 1997).

Method

Subjects. Twenty-seven adult native readers of Turkish, who were undergraduates at Eastern Mediterranean University, took part in this experiment. Each subject received course credit for his/her participation. The subjects were drawn from the same student population as that in Experiment 1.

Materials, Apparatus, and Procedure. The materials and apparatus were the same as those in Experiment 1. Two blocks of trials consisted of either 40 word or 40 nonword stimuli. The order of presentation for both the practice and the test blocks was counter-balanced. Test trials were preceded by two practice blocks, one block of 20 word stimuli and another block of 20 speed-matched nonword stimuli, consisting of the same 40 items as those used in Experiment 1.

Results and Discussion

The mean RTs and associated percentages of errors for each condition can be seen in Table 4. Planned comparisons showed that high-frequency words were named 24 msec more quickly than low-frequency words [$t_s(26) = 2.29$, $SEM = 10.48$, $p < .03$; $t_t(38) = 2.45$, $SEM = 9.65$, $p < .02$]. There was no difference between high-frequency words and their speed-matched nonwords [$t_s(26) = 1.02$, $SEM = 14.81$, $p = .3$; $t_t(38) = 1.52$, $SEM = 9.6$, $p = .14$] or between low-frequency words and their speed-matched nonwords [$t_s(26) = 1.07$, $SEM = 13.82$, $p =$

Table 4
Mean Response Times (RTs, in Milliseconds), Standard Deviations (SDs), and Percentages of Errors to Words and Nonwords in the Two Mixed-Block Conditions (High- and Low-Frequency Words and Their Speed-Matched Nonwords) in Experiment 4

Stimulus Type	RT	SD	% Errors
1. High-frequency words	652	75	0.4
2. Matched nonwords	667	84	0.7
Difference	15		-0.3
3. Low-frequency words	676	85	0.6
4. Matched nonwords	691	93	0.6
Difference	15		0
Nonword effect	24		0.1
Word frequency effect	24		0.2

.29; $t_1(38) = 1.81$, $SEM = 8.1$, $p = .08$]. Again, there were no significant error effects.

A cross-experiment two-way ANOVA between Experiments 3 and 4 yielded a significant main effect of frequency [$F(1,40) = 12.68$, $MS_e = 1,494.87$, $p < .001$]. The main effect of type of blocking was marginal [$F(1,40) = 3.29$, $MS_e = 10,828.91$, $p < .08$]. More critically, there was no interaction between type of blocking and frequency ($F < 1$).

Although the time criterion is neutral as to which route is employed in naming, it is evident that the proportion of stimuli to be named in a block may also have an influence on the placing of the time criterion. The methodological considerations raised earlier, prior to Experiment 3, about how the proportion of stimuli in a block may affect the outcome are relevant here. In Experiment 1, the nonword effect was magnified, as was the word frequency effect, when each type of stimuli was presented in pure blocks. In Experiment 2, both the word frequency and the nonword effects were considerably reduced when words were mixed with their speed-matched nonwords in two blocks. In Experiment 3, there was further reduction of the frequency effect, in comparison with Experiments 1 and 2, when all the words and nonwords were mixed in a single block, but the nonword effect remained the same as that in Experiment 2. In Experiment 4 when words were presented in one block and nonwords in another, the frequency effect stayed the same as that in Experiment 3, but the nonword effect was further reduced to mirror that of the word frequency effect. This finding is the most diagnostic between the two accounts tested here. The reduction in the nonword effect could be attributed to the fact that in Experiment 4, the readers were making optimal use of the nonlexical route to name the nonwords, operating autonomously and in addition to the time criterion—hence, the reduced nonword effect, in comparison with other conditions in which nonwords were mixed with words. It is granted that the magnitude of the nonword effect is an interesting yet secondary issue that could be the subject of further empirical investigation.

To summarize, once again the results from Experiments 3 and 4 are in line with the time criterion prediction of a main effect for word frequency effect but no interaction between type of blocking and frequency. On the other hand, the attenuation account predicts a larger effect for word frequency when words are presented in the absence of nonwords (as in Experiment 4) and, thus, a significant interaction between word frequency and type of blocking. The results clearly demonstrate here that this is not the case. This pattern of results is fully predicted and explained by the time criterion, rather than the attenuation, account. As would be predicted by the time criterion account, the magnitude of word frequency reported in Experiment 4 is similar to that obtained in Experiment 3, despite the fact that words were presented for naming in a single block in the absence of nonwords. Evidence from nonword RTs in Experiment 4 fully sup-

ports the prediction of the time criterion account, indicating that a midpoint in articulation is set irrespective of lexical status of the items in the naming list.

GENERAL DISCUSSION

The issue of whether readers can vary their strategies in response to properties of the stimuli has been the topic of much empirical research, not only in English, but also in other orthographies, such as Persian, Turkish, Korean, and Italian (e.g., Baluch & Besner, 1991; Monsell et al., 1992; Raman et al., 1996; Simpson & Kang, 1994; Tabossi & Laghi, 1992; Zevin & Balota, 2000). The emerging consensus is that readers could switch between the lexical and the nonlexical routes in response to the composition of stimuli. An earlier finding from an investigation of skilled readers in Turkish (Raman et al., 1996), whereby an effect for word frequency was typically eliminated in the presence of nonwords, was also interpreted in these terms. In a series of articles by Lupker and colleagues (Kinoshita & Lupker, 2002; Lupker et al., 1997; Taylor & Lupker, 2001), the time criterion account was offered as an alternative explanation for such findings. The elimination of the word frequency effect when words are mixed together with nonwords is explained by the time criterion as homogenized RTs determined by the difficulty of items to be named.

In the present set of experiments, we sought to establish whether readers of the transparent Turkish orthography adopt strategies by changing routes, as had been widely suggested previously, or whether they simply adjust the point at which an articulation time is released as a function of the average difficulty of all the stimuli they encounter in a block of trials. The results from the present four experiments support an account in which single-word naming in Turkish is strongly influenced by the setting of a time criterion, rather than by a shift from the lexical to the nonlexical route in response to the presence of nonwords. The inclusion of nonwords affects the position of this criterion to the extent that nonword-naming time differs from word-naming time. When nonwords are named as quickly as words (i.e., are speed matched with words), this does not affect the size of the word frequency effect. However, when they are named more slowly than words, as is typically the case, mixing such nonwords with words eliminates the word frequency effect. To summarize, the magnitude of the word frequency effect appears to be dependent on the predictability of the next item in the naming block, so that in Experiment 1, when each stimulus type was presented in pure blocks, a 57-msec word frequency effect was observed. When all the items were mixed in one block in Experiment 3, the effect of word frequency, although statistically significant, was reduced to 26 msec. More critically, we set out to empirically distinguish between the time criterion and the attenuation accounts with Experiment 4. The magnitude for word frequency effect was maintained in Experiment 4 with a 24-msec effect, despite the same high-

and low-frequency words being named in the absence of nonwords. The series of results are fully explained by the time criterion account, whereby a partial or incomplete homogenization of naming RTs was predicted under mixed conditions.

Moreover, a nonword effect parallel to the word frequency effect was seen across the four experiments. In Experiment 1, a 69-msec difference was observed when two types of nonwords, fast and slow, were named in pure blocks. This was reduced to 45 and 44 msec in Experiments 2 and 3, respectively. More important, in Experiment 4, the nonword effect mirrored that of the word frequency effect with a 24-msec difference. Because the impact of placing a time criterion to name stimuli is independent of the nature of the processing—that is, lexical or nonlexical—but is determined by the predictability of the next item to be named, we argue that this effect is bidirectional, which merits further research. That is, the reduction in the word frequency effect for words is reflected in the parallel reduction for the nonword effect across experimental manipulations.

Moreover, a one-way ANOVA was conducted to test whether type of blocking across four experiments would have an effect on word frequency. A null effect ($F < 1$), for type of blocking was taken to indicate that Turkish readers are not as responsive as readers of English to manipulations that are intended to induce strategies in reading. Thus, it appears that neither the lexical nor the nonlexical route is under the strategic control of Turkish readers and that the data are best explained by a time criterion position. The question of whether readers actually have any control over the contribution of each route to pronunciation has also recently been raised by Chateau and Lupker (2003).

Note that readers of English, Persian, or Hebrew or of nonalphabetic scripts, such as Japanese, may be more inclined to use both the lexical and the nonlexical routes “strategically” in naming, prompted by the physical characteristics of their script. This is because readers of such scripts, given the nature of their orthography, may have to *simultaneously* deal with both lexical and nonlexical processing in the course of their reading development. Although English uses a single script, readers must use the lexical route to read irregular words. Persian readers must use a similar strategy to deal with strings of consonantal spelling by employing diacritics. Japanese readers need to employ the lexical route in reading the logographic Kanji. In contrast, at least in principle, the regular words of English, transparent words of Persian, and Japanese Kana can be read via the nonlexical route. Although different strategies are applicable, at least in principle, strategic reading may nevertheless be encouraged by the different spelling structures of one’s own language. One may speculate that because reading Turkish does not dictate the switching of routes, the emerging architecture may essentially discourage strategic reading. It is important to note, however, that during literacy development, a shift from nonlexical to primarily lexical reading

must take place, as is mirrored by the word frequency effect reported here.

On the basis of the above evidence with total lack of support for changing routes, we propose a model in which both lexical and nonlexical processing appears to be in parallel, interactive and equally automated for naming Turkish (and perhaps, for other totally transparent orthographies) minus a flexible switching mechanism. In this respect, factors such as the presence and absence of nonwords, type of blocking, and instruction may indeed impose *task demands* on readers of irregular or opaque orthographies, encouraging them to change or attenuate routes. Arguably, one need not expect the same for readers of Turkish, who never face the type of linguistic dichotomies that exist for scripts such as English and Persian. Thus, neither the presence or absence of nonwords nor blocking need have the same impact on single-word naming in Turkish. That is, there is no change or attenuation in the processing routes for Turkish readers, because it is not a fundamental property of the functional architecture.

One could speculate further by assuming that the peculiarities of English (e.g., regular vs. irregular words) and Persian (e.g., presence vs. absence of vowel diacritics) may demand that readers attend to a particular strategy that will provide the most efficient and successful phonology early on in the process. In the absence of linguistic dichotomies in Turkish, it is not surprising that there is little or no impact of such experimental manipulations. In sum, the impact of the difficulty and predictability of the stimuli takes its toll later on in the process of deriving phonology, just prior to articulation—hence, the effect on the time criterion. It is our contention that the partial homogenization of naming RTs observed here in mixed blocks has the power to explain not only the present set of data, but also data previously reported for Turkish by Raman et al. (1996), for Persian by Baluch and Besner (1991), and for English by Lupker et al. (1997). It is also noteworthy that whereas the time criterion is orthogonal to the number of routes involved in attaining phonology, it is also crucial to establish whether its operations are orthogonal to lexicality.

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APPENDIX

Table A1
High- and Low-Frequency Turkish Words,
With Their Corresponding Translations Into English

High-Frequency Words	Corresponding English Translation	Low-Frequency Words	Corresponding English Translation
açık	open	avuç	palm
aç	hungry/open	ay	moon
anne	mother	ayran	yoghurt drink
bahçe	garden	baston	walking stick
biber	pepper	berber	barber
camı	mosque	cila	varnish
çiçek	flower	çilek	strawberry
dünya	world/earth	dümen	driving wheel
erkek	man	esnek	flexible
fırın	oven	fener	lantern
göz	eye	gaz	gas
güzel	beautiful	gündüz	daytime
halı	carpet	havan	pestle-mortar
insan	human	incir	fig
kan	blood	kaygan	slippery
kilit	lock	küp	large earth-pot
mavi	blue	maske	mask
para	money	peçe	veil
saç	hair	saz	stringed folk instrument
tepsi	tray	türbe	tomb

APPENDIX (Continued)

Table A2
Three- and Four-/Five-Letter Nonword Stimuli Created and Validated in Experiment 1
and Used as Naming Speed-Matched Nonwords in Experiments 2–4

Three-Letter Nonwords	Four-/Five-Letter Nonwords
ako	alif
anu	apuk
api	aruy
bap	bikat
bet	banim
cum	cava
çip	çiren
dof	dopul
elk	evsol
fey	firan
gat	gavar
gep	gacir
hul	hesel
ira	inser
kof	kenip
kuz	kıya
mis	meyu
pap	pesit
sem	sıptak
tes	teley

Table A3
Stimuli Used in Practice Trials in Experiments 1–4

High-Frequency Words	Low-Frequency Words	Three-Letter Nonwords	Four-/Five-Letter Nonwords
ayna	arpa	ars	apran
daire	damar	dan	deset
dosya	damla	düç	darun
hasta	hamam	hit	hıpat
kapı	kıyı	kej	kipat
okul	obur	ofu	orat
oyun	otel	osu	oyus
tarak	tören	til	teley
uyku	uyuz	uka	uvay
yatak	yokur	yup	yulat

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