

## Priming in Pronunciation: Beyond Pattern Recognition and Onset Latency

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Three experiments that address the impact of associative relatedness on both onset latencies and production durations in pronunciation performance are reported. In Experiment 1, a related response cue, presented *after* a to-be-pronounced target word, decreased the target word's production duration, compared to an unrelated response cue, but did not influence its onset latency. In Experiment 2, two related or two unrelated words were simultaneously presented. The response cue was presented 400, 900, 1400, or 1900 ms after the stimuli were presented and indicated whether to pronounce the stimuli in a prepared sequence or in an unprepared sequence. The results indicated that the production durations were shorter when the two words were related, compared to unrelated, independent of cue delay. Also, the onset latencies were faster when the words were related compared to unrelated at each delay except the 1900-ms delay. In Experiment 3, three word sequences were presented to distinguish between associative-cooccurrence accounts and meaning-level accounts of the results obtained in Experiments 1 and 2. The results of Experiment 3 yielded a significant impact of the primes on both onset latencies and production durations. The pattern of priming effects supported a meaning-level account of the present production duration effects. The results from these experiments are interpreted within both an interactive activation model of speech production and a cooperative-based model of language processing. © 1989 Academic Press, Inc.

There has been a considerable amount of research addressing the impact of context on the processing of new input. For exam-

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ple, it has been demonstrated via the "word superiority effect" that a given letter is more easily recognized when it is embedded in the context of a word than when it is presented alone (e.g., Reicher, 1969). Second, it has been demonstrated via the semantic priming effect (e.g., Meyer & Schvaneveldt, 1971) that target words (e.g., *dog*) are more quickly recognized when they are preceded by related prime words (e.g., *cat*), compared to unrelated prime words (e.g., *cup*). Third, it has been shown that reading speed and comprehension are facilitated when a target sentence agrees with the context that has been specified in advance (e.g., Bransford & Johnson, 1972).

Such findings have been at the forefront of the interactive framework in which it is suggested that top-down stored information combines with bottom-up stimulus information to influence which patterns are selected for further processing.

The present research is an extension of this basic interactive framework to processes that occur after pattern recognition has been completed. Specifically, if activation from word levels can influence activation at letter levels, as the word superiority effect suggests, then it is possible that activation resulting from a relationship between words may also feed down to influence the speed of sequencing of motor codes that correspond to the sounds (e.g., phonemes) that are produced during pronunciation.

Recently, there has been an increasing interest in processes that occur after stimulus recognition in the two tasks commonly used to study word recognition, i.e., the lexical decision task (LDT) and the pronunciation task. For example, recent discussions of the LDT have suggested that a number of variables that were previously thought to influence only the pattern-recognition system also extend their influence to processes that are involved in the decision component of that task (Balota & Chumbley, 1984; Chumbley & Balota, 1984; Forster, 1981; Kiger & Glass, 1983; Lorch, Balota, & Stamm, 1986; Neely, 1986; Seidenberg, Waters, Sanders, & Langer, 1984; West & Stanovich, 1982). Furthermore, Balota and Chumbley (1985) have recently suggested that part of the influence of word frequency in the pronunciation task involves processes that occur after the stimulus has been recognized (also see, Theios & Muise, 1977). Because of the relevance of the Balota and Chumbley (1985) study, their research will be briefly outlined.

Balota and Chumbley used a delayed pronunciation task to address whether frequency has any postrecognition influence in pronunciation. In the delayed pronunci-

ation task, the subject is presented a to-be-pronounced word and after some delay is given a cue to pronounce it aloud. If sufficient time has passed between the presentation of the word and the presentation of the cue (e.g., one second), one might assume that pattern-recognition processes have been completed. Therefore, any remaining impact of a variable, in this case frequency, should be on processes after word recognition. Balota and Chumbley found that subjects were still slower to pronounce low-frequency words than high-frequency words even though they were given up to 1400 ms to recognize the stimulus. On the basis of a series of three experiments, Balota and Chumbley suggested that the impact of word frequency was not limited to pattern-recognition processes but also extended to processes beyond pattern recognition.<sup>1</sup>

The current study extends the Balota and Chumbley research to a contextual variable. The variable chosen was associative relatedness. As noted, target words (e.g., *dog*) are recognized more quickly when preceded by related prime words (e.g., *cat*) than when preceded by unrelated prime words (e.g., *cup*). The traditional account of this finding is that activation from the prime (*cat*) spreads along associative pathways to related areas in the memory system. One of these related areas would represent the target word, and therefore its corresponding lexical representation would be preactivated. Because the target word's memory representation is preactivated by the related prime, less visual stimulus information is needed to recognize the target word, compared to an unrelated prime condition.

<sup>1</sup> We are not suggesting that the input and output processes are completely separate and serial stages of processing such that one stage must be completed before the next stage begins. In fact, we are suggesting the opposite, in that there is a much more continual flow of information in a cascade-like manner (McClelland, 1979). The terms *input* and *output* are used simply to reflect relative positions in the cascade.

On the basis of this framework, researchers have argued that contextual relatedness influences the word recognition stage of processing. Furthermore, researchers appear to suggest that the impact of relatedness ends at the pattern-recognition stage in simple pronunciation (e.g., Balota & Lorch, 1986; Seidenberg et al., 1984; West & Stanovich, 1982). After pattern recognition is completed, the subject accesses the phonological codes that are connected to the word's lexical representation and "triggers" these codes to pronounce the word aloud. The question addressed in the present research is whether the impact of contextual relatedness ends at the pattern-recognition stage of processing. Could it be that the relationship between *dog* and *cat* still influences performance at some stage after lexical access has occurred?

There is clear theoretical motivation for expecting such postrecognition influences. According to the interactive activation models (e.g., McClelland & Rumelhart, 1981; Dell, 1986), activation at one level in the system can influence the amount of activation in other levels in the system in a cascade-like fashion. Activation does not simply stop at any particular stage of processing. Thus, if a memory representation receives additional activation because of the processing of a related neighbor, then one might expect this additional activation to continue throughout the processing tied to the target.

#### EXPERIMENTS 1 AND 1A

Experiment 1 involved a variant of the delayed pronunciation task. On each trial, a to-be-pronounced target word was presented and then after varying delays the target word was replaced by a prime cue that signaled the subject to pronounce the target word aloud. The prime cue was related to the first word, unrelated, or a neutral row of xs. For example, the word *dog* might be the to-be-pronounced target word on a given trial. After 800 ms the word *dog* might be replaced by the related word *cat*, the unre-

lated word *cup*, or *xxxx*. The subject's task is simply to pronounce *dog* when it is replaced by the response cue. It is important to note that this is a *simple reaction time task*; i.e., there is no need to process the response cue beyond the fact that it represents a change in stimulus. The varying delays allow one to trace the temporal characteristics of the spread of activation.

The predictions are straightforward. If the relationship between the target word and the response cue influences postrecognition processing, then one would expect that response latency to pronounce *dog* would be faster when it is cued by the related word *cat* than when it is cued by the unrelated word *cup*. In addition to measuring onset latencies, the present experiments also provide information regarding production durations. Such production durations ideally reflect the time from the onset of the first sound to the offset of the last sound in the production of the target word. As far as we are aware, this is the first investigation of the impact of associative context on the durations of single word pronunciation performance. Any influence of the relationship between the target word and the response cue on the durations of the response would appear to reflect a postrecognition influence (see, however, Footnote 1).

In order to ensure that the stimulus set produced priming effects in a normal forward priming task, an additional experiment was conducted. For simplicity, we refer to this experiment as Experiment 1A. This experiment involved the same materials and delays as the delayed pronunciation procedure described above, but the subject's task was different. In Experiment 1A, the subject simply pronounced the second word aloud as soon as it was presented instead of pronouncing the first word when the second word was presented. This experiment provides an interesting comparison to Experiment 1 because across the two experiments, one can trace the activation *forward* from the prime to the target in Experiment 1A and, in some sense, *backward*

from the prime to the target in Experiment 1. The delays between the prime and the target ranged from 150 to 1150 ms in Experiment 1A and the delays between the target and the prime ranged from 150 to 1150 ms in Experiment 1.

### Method

*Subjects.* Forty-five undergraduates participated in Experiment 1 and 45 participated in Experiment 1A. All were native English speakers and all participated in partial fulfillment of a course requirement at Iowa State University. No subject participated in more than one of the experiments presented in this paper.

*Apparatus.* Stimulus presentation and data collection were controlled by an Apple IIe computer that was interfaced with a Mountain Hardware clockboard that provided millisecond accuracy. The computer was also interfaced with a Gerbrands G1341T voice-operated electronic relay to obtain both onset latencies and production durations. Assembly language subroutines were written to sample the state (e.g., open or closed) of the voice-operated relay.

*Materials.* The critical stimuli were based on 150 high-associate pairs that were selected from stimulus sets used in previous papers addressing semantic priming effects (Balota, 1983; Balota & Lorch, 1986; Lorch, 1982). For each stimulus pair, one word was selected as the prime item and one word was selected as the target. In addition to the 150 critical test pairs, an additional 44 pairs were selected as practice/buffer prime-target pairs. All words ranged from 3 to 9 letters in length and all were common medium- to high-frequency words.

Each subject first received a practice list of 36 target-prime pairs in Experiment 1 or 36 prime-target pairs in Experiment 1A. The practice trials were followed by two test blocks with 79 trials in each block. The first four trials in each test block were buffer trials. The three prime-target conditions for Experiment 1A were related (e.g.,

*cat-dog*), neutral (e.g., *xxxxx-dog*), and unrelated (e.g., *cup-dog*), and the three target-prime conditions for Experiment 1 were related (e.g., *dog-cat*), neutral (e.g., *dog-xxxxx*), and unrelated (e.g., *dog-cup*). Within the practice block there were 12 trials of each condition and within the critical 75 trials of each test block there were 25 trials of each condition. The four buffer trials at the beginning of each test block included two related, one neutral, and one unrelated trial.

The unrelated prime items for the first block of test trials were selected from the pool of words that served for different subjects (because of counterbalancing) as the related prime items for the targets in the second block of test trials, and the unrelated prime items for the second block of test trials were selected from the pool of words that served for different subjects as the related prime items for the targets in the first block of test trials. This selection process was conducted anew for each subject. In this way the prime items occurred in both the related and the unrelated conditions, no item was repeated for a given subject, and the pairing of a given prime with a given target in the unrelated condition changed across subjects to avoid any potentially contaminating phonemic relationships between the targets and the primes.

Each target word was counterbalanced across each of the 15 conditions (3 prime conditions  $\times$  5 delays) across each group of 15 subjects. After items were assigned to conditions, the practice trials and the 75 target trials within the test blocks were randomly ordered anew for each subject.

*Procedure.* For Experiment 1A, the following sequence of events was presented on each trial: (a) a row of three asterisks separated by blank spaces in the center of the screen for 275 ms; (b) a blank screen for 275 ms; (c) a tone for 250 ms; (d) a blank screen for 275 ms; (e) the priming stimulus for 150, 400, 650, 900, or 1150 ms; (f) the target word replaced the prime and remained on the screen until the subject pro-

nounced it aloud; (g) a 300-ms blank screen; (h) the message "IF YOU CORRECTLY PRONOUNCED THE WORD, PRESS THE '0' BUTTON, OTHERWISE PRESS THE '1' BUTTON"; (i) the subject pressed either the "0" button or the "1" button; (j) a blank screen for 3 s. The only difference between Experiment 1 and Experiment 1A is that in Experiment 1 the sequence of the prime and target items was reversed and subjects pronounced the first word when the second word was presented.

In Experiment 1A, subjects were instructed that they would be presented with a pair of stimuli on each trial. They were told that the initial stimulus might be a row of xs or a word and the second stimulus would always be a word, and that their major task was to pronounce the second word as quickly and as accurately as possible. They were told that if they felt their correct pronunciation triggered the computer, then they should press the "0" button after they pronounced the word; if they felt that an incorrect pronunciation or an extraneous sound triggered the computer, then they should press the "1" button. The experimenter demonstrated to the subject how the voice key picked up sound and triggered the erasure of the stimulus.

The instructions were the same for Experiment 1 except that subjects were instructed to pronounce the first word then the second stimulus appeared. Emphasis was placed on this instruction to avoid any false starts, i.e., beginning the pronunciation of the first word before the second stimulus was presented. The instructions also emphasized that the subjects did not need to respond in any way to the second stimulus, and that they should respond as soon as they detected any change on the screen.

There were three break intervals in each experiment. The experimenter stayed with the subjects for the first 18 practice trials to ensure that subjects understood the instructions. There was a short 30-s break period at this point and also a 1-min break at the

beginning of each of the test blocks. The experiments were conducted in a small sound-deadened testing room.

## Results

In each of the experiments reported, a mean response latency was calculated for each subject/cell. Responses were not included if they met one of the following conditions: (1) the subject typed a "1" indicating that the correct pronunciation did not trigger the computer or (2) the onset latency was either below 150 ms or above 1000 ms.

An analysis of variance (ANOVA) was initially conducted on both the subjects' mean response latency and the production duration per condition to determine if there were any main effects or interactions. Planned comparisons were conducted to specify the nature of any significant effects. Unless otherwise noted, all effects that are referred to as significant have  $p$  values  $< .05$ .

*Experiment 1A: Onset latencies.* Figure 1 displays the mean onset latencies as a function of Prime and Delay for Experiment 1A. There are three points to note in Fig. 1. First, the related condition produced faster response latencies than the neutral and unrelated conditions. Second, the response latencies decreased as delay increased from 150 to 400 ms. Third, the neutral condition

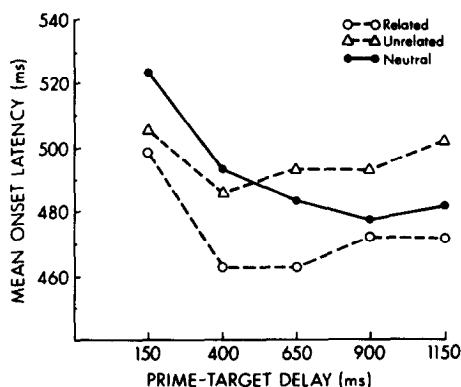


FIG. 1. Mean onset latency for the related, neutral, and unrelated conditions as a function of prime-target delay.

produced slower response latencies than both the related and the unrelated conditions at the shortest delay but by the longest delay the neutral condition only produced slower response latencies than the related condition.

The above observations were supported by a 3 (Prime)  $\times$  5 (Delay) within-subjects ANOVA. This analysis yielded a significant main effect of Prime,  $F(2,44) = 33.33$ ,  $MSe = 966$ , and Delay,  $F(4,176) = 21.90$ ,  $MSe = 977$ , along with a significant Prime  $\times$  Delay interaction,  $F(8,352) = 5.84$ ,  $MSe = 588$ .

The results of Experiment 1A clearly indicate that there is a readily available relationship between the primes and the targets. Moreover, the onset latencies conform to the pattern of facilitation and inhibition effects predicted by the Posner and Snyder (1975) framework and supported by the lexical decision research of Balota (1983), Favreau and Segalowitz (1983), and Neely (1977). Basically, at the two shortest delays one finds facilitation of the related condition with no inhibition of the unrelated condition, but at the longest two delays one finds evidence for both facilitation of the related condition and inhibition of the unrelated condition. Although this finding is noteworthy because, as far as we are aware, this is the first demonstration of a buildup of inhibition across delays in a pronunciation task, our major interest in the present research is in the influence of the prime-target relationship on output processes and, therefore, we now turn to the production durations of Experiment 1A.

*Experiment 1A: Production durations.* The production durations ideally refer to the time between the beginning of the production of the first sound and the end of the production of the last sound in the word. It should be noted that because a voice key was utilized there will be error in these estimates, but because all stimuli occurred in all conditions, any such error will not be systematic. The production durations are noteworthy for two reasons. First, we are

unaware of any research available addressing associative influences on the production durations of single words, and second, any impact of relatedness on production durations would clearly be an influence of this variable on output processes.

Figure 2 displays the production durations for Experiment 1A. As shown in Fig. 2, the only consistent pattern in these data appears to be that the neutral and related conditions produce slightly shorter production durations than the unrelated condition, especially at the three shortest delays, and the production durations appear to increase slightly across the delays. However, an ANOVA indicated that neither the main effect of Prime,  $F(2,44) = 2.12$ ,  $MSe = 824$ ,  $p = .12$ , or Delay,  $F(4,176) = 1.67$ ,  $MSe = 929$ ,  $p = .16$ , nor the interaction between these two variables reached significance,  $F(8,352) = .68$ ,  $MSe = 661$ .

*Experiment 1A: Percentage correct.* An ANOVA was also conducted on the mean percentage correct, i.e., the percentage of trials in which the subject pressed the "0" button to indicate that the previous trial was correctly performed (see method section) and the response latency was not an outlier. This analysis yielded only a main effect of prime type,  $F(2,88) = 11.5$ ,  $MSe = .344$ , which indicated that the related condition produced higher accuracy (98%)

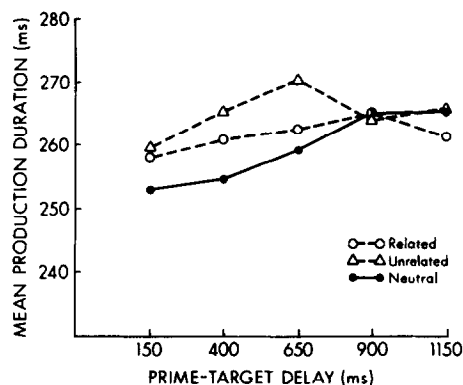


FIG. 2. Mean production duration for the related, neutral, and unrelated conditions as a function of prime-target delay.

than the neutral (96%) and the unrelated (95%) conditions.

The results of Experiment 1A indicate that in the typical forward priming situation there was a substantial decrease in response latency for a target word when it was preceded by a related prime, compared to an unrelated prime. Also, there appeared to be some tendency for the related and neutral conditions to produce slightly shorter production durations than the unrelated condition, although this difference did not reach significance. We now turn to the results of Experiment 1 to address whether there is any influence of prime relatedness after the subjects received sufficient time to process the targets in the delayed pronunciation task.

**Experiment 1: Onset latencies.** The mean onset latencies for Experiment 1 as a function of Prime and Delay are presented in Fig. 3. There are two major points to note in Fig. 3. First, response latencies dramatically decreased as the delays increased. This, of course, was expected because as subjects were given more time to process the target word, they should have completed more of the "earlier" processes such as lexical access. Second, although the neutral condition produced faster response latencies than the related and unrelated conditions at the shortest and at the longest

delay conditions, there was very little difference between the related and the unrelated conditions.

The ANOVA yielded significant main effects of Prime,  $F(2,44) = 4.64$ ,  $MSe = 1110$ , and Delay,  $F(4,176) = 108.78$ ,  $MSe = 1978$ . It is noteworthy that the influence of Prime is due to the fact that the neutral condition produced overall faster response latencies than the remaining two conditions. In fact, both the related and the unrelated conditions produced equivalent mean onset latencies of 355 ms. Finally, the interaction between Prime and Delay did not reach significance,  $p > .20$ .

**Experiment 1: Production durations.** The mean production durations for Experiment 1 as a function of Prime and Delay are displayed in Fig. 4. There are two major points to note in Fig. 4. First, the related prime condition produced shorter production durations than the unrelated prime condition, primarily at the 400- and 650-ms delays. Second, the neutral prime condition produced shorter production durations than the unrelated prime condition at all delays except the shortest delay.

The above observations were again supported by an ANOVA. There was a marginally significant main effect of Prime,  $F(2,44) = 2.99$ ,  $MSe = 958$ ,  $p = .054$ , and a significant interaction between Prime and

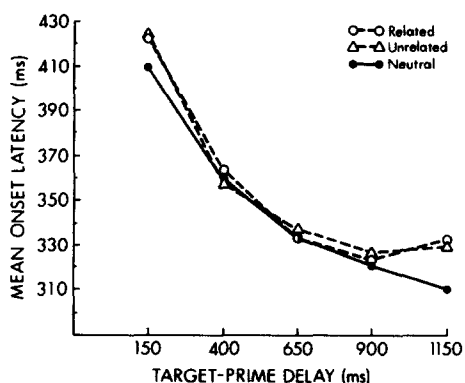


FIG. 3. Mean onset latency for the related, neutral, and unrelated conditions as a function of target-prime delay.

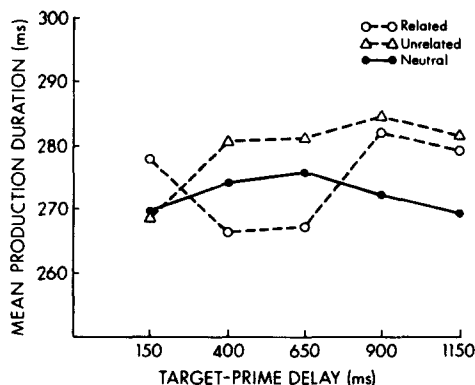


FIG. 4. Mean production duration for the related, neutral, and unrelated conditions as a function of target-prime delay.

Delay,  $F(8,352) = 2.54$ ,  $MSe = 632$ . The main effect of Delay did not approach significance,  $p > .25$ .

Because the neutral condition may have produced relatively shorter production durations due to less attentional demands or possibly due to less interference with activated motor codes, and because our primary interest is in the impact of associative relatedness between words, it might prove useful to directly compare only the related and the unrelated cue conditions.<sup>2</sup> Therefore, a 2 (Related vs Unrelated)  $\times$  5 (Delay) ANOVA was conducted. This analysis yielded a significant main effect of Prime,  $F(1,44) = 4.69$ ,  $MSe = 522$ , and a significant Prime  $\times$  Delay interaction,  $F(4,176) = 3.78$ ,  $MSe = 555$ . Post hoc comparisons yielded significant facilitation of the related condition compared to the unrelated condition at the 400-ms delay,  $t(44) = 3.27$ ,  $p < .005$ , and at the 650-ms delay,  $t(44) = 2.48$ ,  $p < .02$ . None of the remaining delay conditions produced a significant effect of relatedness.

*Experiment 1: Percentage correct.* An ANOVA on the percentage correct data yielded only a main effect of Delay,  $F(4,176) = 7.52$ ,  $MSe = .882$ , which indicated that accuracy decreased with increasing delays. This probably occurred because subjects were more likely to "jump the gun" at the longer delays and pronounce the word or make some sound before the prime was presented.

### Discussion

The results of Experiments 1A and 1 are clear. First, the large priming effects in the forward priming Experiment 1A indicated that there was a readily available association between the prime and the target items. Although there was some tendency in this experiment to also produce influences on production durations, these ef-

fects did not reach significance. Second, in the backward priming Experiment 1, there was a large impact of delay. This was expected because the delays allowed the subjects time to complete early pattern recognition processes. Third, the neutral prime produced facilitation in the onset latencies of Experiment 1 compared to the two word-prime conditions. This might reflect a type of forced processing of lexical cue items and is reminiscent of the Stroop (1932) effect (also see Balota & Rayner, 1983; LaBerge, 1973). Fourth, there was very little impact on onset latencies due to the associative relationship between the prime items and the to-be-pronounced targets. Thus, given this finding one might argue that there was no impact of cue relatedness past pattern-recognition processes. Finally, and most interesting, there was evidence of an impact of the type of cue on the production durations of the targets. The production durations were significantly shorter when the cue was related to the target than when the cue was unrelated to the target. This impact occurred primarily at the 400- and 650-ms delay conditions.<sup>3</sup>

The impact of cue relatedness on production durations is interesting because it suggests that associative information is actually influencing the rate at which the motor codes that are used to pronounce words are implemented. Such an effect is intriguing

<sup>3</sup> At attempted replication of Experiment 1, with fewer subjects (30), produced the same overall pattern of data. The major difference in the replication was that the response cue flanked the target both immediately above and immediately below the target, and the target remained on the screen throughout the production. The results again indicated that the neutral prime condition produced faster onset latencies than the word prime conditions, and this effect occurred primarily at the 150- and 400-ms delays. More importantly, although the main effect of prime did not reach significance in the production durations ( $p = .13$ ), planned comparisons indicated that the related condition produced significantly shorter production durations than the unrelated condition at the 400-ms,  $t(29) = 2.18$ , and 900-ms cue delays,  $t(29) = 1.68$ ,  $p < .05$ , one-tailed. None of the remaining comparisons reached significance.

<sup>2</sup> Jonidis and Mack (1984) and de Groot, Thomasen, and Hudson (1982) provide further discussion of the problems associated with achieving a truly neutral baseline in word recognition experiments.



for the following two reasons. First, it is unclear how subjects could still be engaged in the recognition of the target word after a 650-ms preview. Second, because the influence is on production *durations*, relatedness is influencing "how" the subject produces the word, not simply "when." As noted earlier, such an impact of relatedness might be expected based on a highly interactive language-processing system.

There are a number of further aspects of Experiment 1 that need to be addressed. First, the failure to find evidence of associative backward priming in the onset latencies does not replicate the backward priming effects reported by Kiger and Glass (1983). Although there are a number of differences between the present study and the Kiger and Glass study (e.g., lexical decision vs pronunciation), the most notable difference was that the SOAs between the target and the prime in the Kiger and Glass study were shorter than those in the present experiment. In the Kiger and Glass study, the SOA was 65 ms in Experiment 2 and 50 ms in Experiment 3, whereas in the present Experiment 1, the minimum SOA was 150 ms. In fact, in Kiger and Glass's first experiment, they did not find a significant priming effect when the SOA was 130 ms. Thus, the delays used in the present research were possibly too long to find the same type of backward priming found by Kiger and Glass.

A second aspect to note about the present data is that it is a priori unclear why one would find an impact of associative information on production durations but not on onset latencies. However, if this associative effect is occurring at the speed at which phonemes are selected and activated, it is possible that the production results reflect a multiplicative effect of this activation. Because onset latencies reflect only the time to select and implement one phoneme whereas production durations reflect the time to select and implement multiple phonemes, possibly the influence of cue relatedness is larger in production du-

rations because its influence summates across the selection of each of the phonemes.

A third question that needs to be addressed in these data is why the associative influences in production occur only within the 400- to 900-ms delay range (see Footnote 3). Consider the possibility that at the shortest 150-ms delay there was insufficient encoding of the to-be-pronounced target word to substantially activate related representations. This preactivation of related representations would have the impact of speeding up the lexical access of the prime cue, thereby increasing its influence back to the target item. Thus, it is possible that at the 150-ms delay there was not enough time for the pathway between the prime and the target to be sufficiently activated before the production was completed. In fact, if one considers the forward priming effect from Experiment 1A (see Fig. 1), the finding of a relatively small associative influence at the 150-ms delay is consistent with this notion.

With respect to the lack of an impact of the associative relationship at the longer delays, it is possible that subjects may have been relatively well prepared when the response cue was presented at the longer delays. Thus, subjects could respond to the prime as a simple response cue before they processed its relationship to the target.

## EXPERIMENT 2

The results of Experiment 1 suggest that the impact of associative-level information on productions is restricted in time, and it was suggested that this occurred primarily because of the time course of activation and the processing constraints in the delayed pronunciation paradigm. In Experiment 2 an attempt was made to keep the activation between two words available for longer delays. In this experiment, on each trial two words were simultaneously presented, one above the other, and after some delay a cue was presented to pronounce both words aloud. The randomly varying cue delays in

this experiment were relatively longer than in the previous experiment, i.e., 400, 900, 1400, and 1900 ms. The notion is that if both words are presented together, their associative relationship should remain active until they are produced. Thus, one might find associative effects in production durations across all delays.

A second issue addressed in this study was the impact of preparation on the response. On 75% of the trials the subjects were given a response cue to produce the words in the prepared fashion, i.e., the top word first and then the bottom word. On the remaining 25% of the trials, subjects were given a response cue to reverse their production, i.e., the bottom word first and then the top word. This manipulation was included to address two issues. First, we were interested in whether the complete production program is prepared before the first phoneme is produced. If this is the case, then one might expect a large impact of preparation on onset latencies but relatively little impact on production durations. Second, the manipulation of preparation along with relatedness might provide some information regarding the locus of the impact of relatedness, e.g., during preparation or during execution. Given additive-factors logic (Sternberg, 1969), if preparation and relatedness influence the same process then one might expect interactive effects of the two variables.

### *Method*

*Subjects.* Thirty-two undergraduate students from Washington University participated.

*Apparatus.* The same apparatus used in the earlier experiments was used in Experiment 2. The only difference was that there was a modification in the software program such that a 300-ms continuous silent period was necessary before specifying the end of a production. This was included to avoid the problem of considering silence within a word such as that produced by voiceless stops as the end of the production. Al-

though any such errors would be randomly distributed across conditions, this change in software should provide a more accurate measure of the production durations.

*Materials.* The critical stimuli were based on 320 pairs of associatively related words selected from the same norms used for item selection in the earlier experiments, along with some associatively related items that two of the authors generated. For each of the critical pairs, one word was designated as the initial word and the second word was designated as the final word with respect to the order of pronunciation. In addition to the 320 critical test pairs, there were an additional 44 pairs generated for practice/buffer trials. All words ranged from 3 to 9 letters in length and all were medium- to high-frequency words.

Each subject first received a practice list that contained 36 pairs of words that were followed by two blocks each containing 164 pairs. The first four trials in each test block were buffer trials. The two major types of trials were related (e.g., *dog-cat*) and unrelated (e.g., *cup-cat*) pairs. As in Experiments 1 and 1A, the unrelated pairmates for the first block of test trials were selected from the pool of words that served for different subjects (because of counterbalancing) as the related pairmates for words in the second block of test trials, and vice versa. This selection of unrelated pairmates for a given target was conducted anew for each subject. Thus, as in the earlier experiments, pairmates occurred in both related and unrelated conditions, no item was repeated for a given subject, and the pairing of a given pairmate with a given target in the unrelated condition changed across subjects to avoid any potentially contaminating pairmate-target phonemic relationships.

Items were counterbalanced across the 2 (related vs unrelated pairs)  $\times$  4 (400-, 900-, 1400-, 1900-ms cue delay) conditions across each group of 8 subjects. In addition, after each group of 8 subjects, the items in the unprepared condition were exchanged with

25% of the items in the prepared conditions. Thus, across the 32 subjects all items occurred equally in all conditions.

The practice list included 18 related and 18 unrelated pairs with 27 in the prepared condition and 9 in the unprepared condition. The delay conditions were randomly distributed across the practice items. The buffer trials included the same ratio as the test trials with respect to relatedness and preparation, with the delays being randomly determined. After items were selected for presentation, they were randomly ordered anew for each subject.

**Procedure.** On each trial the following sequence occurred: (a) a row of three asterisks separated by blank spaces in the center of the screen for 275 ms; (b) a blank screen for 275 ms; (c) a tone for 250 ms; (d) a blank screen for 275 ms; (e) the to-be-pronounced pair of words in the center of the screen, one above the other with a blank line between them; (f) after the predetermined cue delay, the response signal which was either a row of five plus signs (+ + + + +) for the prepared response or five minus signs (— — — — —) for the unprepared response in the line between the two words; (g) the subject pronounced the words in the top-to-bottom prepared direction or the bottom-to-top unprepared direction; (h) a 300-ms blank screen; (i) the message "IF YOU CORRECTLY PRONOUNCED THE WORDS, PRESS THE '0' BUTTON, OTHERWISE PRESS THE '1' BUTTON"; (j) after a button press, a blank screen intertrial interval for 2 s.

Subjects were instructed to pronounce both words on each trial. They were told that as soon as the words were presented on the screen to prepare to pronounce them in the top-to-bottom direction. They were also told that on 75% of the trials they would receive the row of pluses as their cue to pronounce the words in the prepared direction and on 25% of the trials they would receive the row of minuses as their cue to pronounce the two words in the bottom-to-top direction. The instructions empha-

sized that in order to maximize speed and accuracy, the subjects should always prepare their productions in the top-to-bottom direction and when the cue was presented that they should pronounce the words as quickly as possible without producing any mispronunciations. Subjects were also told that if they felt their correct pronunciation triggered the computer, then they should press the "0" button after they pronounced the word, whereas if they felt that an incorrect pronunciation or an extraneous sound triggered the computer, then they should press the "1" button. The experimenter remained in the testing room for the first 16 trials to ensure that subjects understood the instructions. Each subject was run individually in a sound-deadened chamber.

After each group of 40 trials subjects received feedback regarding their overall response latency and their percentage correct. The subjects were told to keep their response latency low and their accuracy high.

## Results

**Onset latencies.** Figure 5 displays the mean onset latencies as a function of Preparedness, Relatedness, and Delay. There are three points to note about the data displayed in Fig. 5. First, as expected, the onset latencies were considerably faster in the

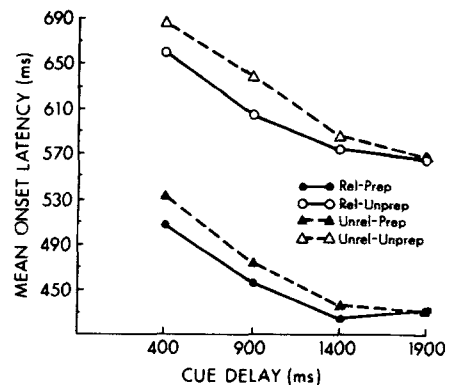


FIG. 5. Mean onset latency as a function of Preparedness, Relatedness, and Cue Delay.

prepared conditions than in the unprepared conditions. Second, also as expected, the response latencies decreased across the delays. Third, there was a relatedness effect that decreased across the delays until it was no longer evident at the longest 1900-ms delay.

The above observations were supported by a 2 (Preparedness)  $\times$  2 (Relatedness)  $\times$  4 (Delay) within-subjects ANOVA. This analysis yielded main effects of Preparedness,  $F(1,31) = 158.10$ ,  $MSe = 17845$ , Relatedness,  $F(1,31) = 19.07$ ,  $MSe = 1849$ , and Delay,  $F(3,93) = 72.30$ ,  $MSe = 3574$ . This analysis also yielded a significant Relatedness  $\times$  Delay interaction,  $F(3,93) = 4.16$ ,  $MSe = 1142$ , that indicates that the relatedness effect decreased across delay. Post hoc comparisons at each of the delays indicated that the only delay that did not produce a significant associative influence was the 1900-ms cue delay.

*Production durations.* Figure 6 displays the production durations as a function of Preparedness, Relatedness, and Delay. There are two points to note in Fig. 6. First, there was some evidence of an impact of preparedness on the production durations because the durations in the prepared condition were shorter than those in the unprepared condition. Second, there was also an impact of associative relatedness because the related condition consistently produced shorter production durations than the unre-

lated condition. The only exception to this pattern was the shortest delay condition for the unprepared condition.

The above observations were supported by an ANOVA on the mean production durations. This analysis yielded a highly significant effect of Relatedness,  $F(1,31) = 15.72$ ,  $MSe = 6660$ . The impact of Preparedness did not reach significance,  $F(1,31) = 3.07$ ,  $MSe = 5704$ ,  $p < .10$ .

*Percentage correct.* The ANOVA on the percentage correct data yielded a main effect of Preparedness,  $F(1,31) = 28.70$ ,  $MSe = 45$ , that indicated that accuracy was higher in the prepared than in the unprepared condition, and a main effect of Delay,  $F(3,93) = 3.0$ ,  $MSe = .46$ , that indicated that accuracy was higher at the shorter than at the longer delays. As in Experiment 1, this latter effect was most likely due to false starts during the longer delays.

### Discussion

The results of Experiment 2 are quite clear and provide two important patterns of data that suggest that there are influences of associative information after pattern recognition. First, the onset latencies indicated that subjects were still faster to begin their pronunciations for related words than for unrelated words, even though they were given 1400 ms to recognize the two words. It is unclear how subjects could still be recognizing the words at the 1400-ms delay condition when one considers that normal reading rates are on the order of 200 ms per word (see Balota & Chumbley, 1985; Neisser & Beller, 1965; Sabol & DeRosa, 1976, for a discussion of estimates of lexical-access time).

The present onset latency results are consistent with results obtained by Dallas and Merikle (1976) and Midgley-West (1979). In both of these studies, associative effects were found after a delay of at least 1 s. The major difference between these earlier studies and the present Experiment 2 is that in the earlier studies each of the stimuli displayed on a give trial was equally likely

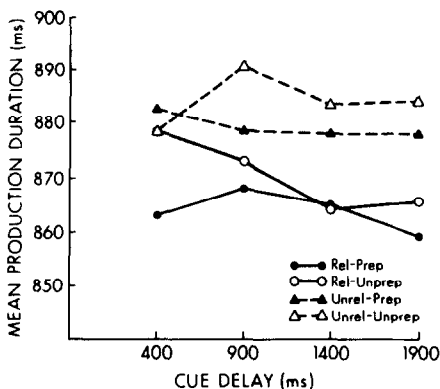


FIG. 6. Mean production duration as a function of Preparedness, Relatedness, and Cue Delay.

to be cued. Therefore, there was no direct attempt to have subjects "prepare" a given response. However, the fact that subjects were showing large associative effects after a 1-s delay still presents difficulties for any model that attributes the associative effects in pronunciation totally to pattern-recognition processes.

The second important aspect of Experiment 2 was that the production durations were shorter in the related condition than in the unrelated condition. This finding supports the earlier results from Experiment 1 in suggesting that relatedness not only influences "when" a word is produced but also can influence "how" the word is produced. A major extension in Experiment 2 was that relatedness influenced production performance across all the delays. As noted above, it was possible that because of the temporal processing constraints of the delayed pronunciation task used in Experiment 1, the influence of relatedness was restricted to the 400- to 900-ms delay ranges (see Footnote 3). Thus, Experiment 2 indicates that if the two words are available throughout the delay period, there will be sufficient activation from their associative relationship to influence production durations across the delays.

Experiment 2 also yielded data regarding the impact of preparation on both onset latencies and production durations. There was a very large impact of preparation on onset latencies, with a relatively small impact of preparation on production durations. This latter effect did not reach significance. Thus, it appears that most of the production is well-prepared before the production begins.

It was also found that the effects of preparedness and relatedness on the onset latencies were additive.<sup>4</sup> According to addi-

tive-factors logic, this would suggest that the two variables were influencing separate stages of processing. We propose the following as a tentative account of this additivity. Because subjects could not predict when the response cue would be presented, they refreshed the output codes for the prepared response in a rehearsal-type fashion during the delay period. When the response cue was presented, the subjects either output the prepared response or switched the retrieved output codes to produce the unprepared response. The additive effect of relatedness and preparedness could have been due to relatedness influencing the refreshing process and preparedness influencing the switch process. An interesting implication of this pattern is that subjects apparently could switch their output codes without retrieving further information from long-term memory.<sup>5</sup> That is, if retrieval

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preparation at the 400-ms delay condition. However, a contrast at this delay indicated that the interaction between preparation and relatedness did not reach significance.

<sup>5</sup> In an unpublished paper, Meyer, Sternberg, Knoll, and Wright (1978) reported an interaction between preparation and relatedness. They found that relatedness had an influence only in the unprepared conditions. This pattern contrasts with the present results in which relatedness had an impact in both prepared and unprepared conditions. However, there is an interesting difference in the procedure used by Meyer et al. that may account for the discrepancy in results. In the Meyer et al. study there was a 4-s delay after the target pair was presented after which there were two warning signals indicating that the response signal would be immediately presented. Thus, subjects had considerable time to prepare their response and, more importantly, could predict when the response signal would be presented. It is possible that because subjects knew precisely when the response cue would be presented, subjects loaded their response into an output buffer, as Meyer et al. argued. In the presented study, because the delays randomly varied, subjects could not predict when the response cue would be presented and therefore could not load their motor program into such a response buffer. This difference in level of preparation is further strengthened by the fact that in the present study overall response latency at the longest delay in the prepared condition was 430 ms, whereas in Meyer et al.'s study overall response latency was approximately 265 ms in the prepared condition.

<sup>4</sup> Because preparation had a relatively small influence on production durations, one cannot provide a strong test of whether relatedness had additive or interactive effects with preparation on production durations. As shown in Fig. 6, there appears to be some evidence of an interaction between relatedness and

from long-term memory is influenced by relatedness, then preparedness and relatedness should have interacted in this experiment. However, there was little evidence for such an interaction. Finally, because the effect of relatedness decreased across delays (see Fig. 5), it appears that the refreshing process may have produced activation for these output codes that eventually reached asymptotic levels for both the related and the unrelated conditions at the longest delay.

There is one final issue that should be noted regarding Experiment 2. It is possible that the production duration effects might be due to the priming of the second word via the pronunciation of the first word. Possibly, the interval between the end of the first word and the beginning of the second word was shorter in the related condition than in the unrelated condition. Although this is possible, it is unlikely because the prepared production of two words in a simple reaction time task is rather continuous. There is little, if any, pause between the output of two words. Furthermore, the results of Experiment 3 provide further data that indicate that this possibility is incorrect.

### EXPERIMENT 3

In Experiment 3, an attempt was made to distinguish between two alternative accounts of the obtained priming effects on production durations. One account is that these effects simply reflect associative-cooccurrence influences that do not depend upon meaning-level information. For example, the word *dog* could prime the word *cat* because the words *dog* and *cat* often co-occur (either in perception or in production) in the language and not because they overlap in meaning (see Lupker, 1984, for a detailed discussion of this distinction). Such priming might reflect a type of intralexical priming. On the other hand, the word *dog* could prime the word *cat* because of the conceptual relationship between the two words. Both words refer to four-legged

mammals, types of pets, etc. This latter type of priming would reflect a semantic (meaning-level) priming effect.

Experiment 3 involved a three-word priming procedure based, in part, on the research of Schvaneveldt, Meyer, and Becker (1976). There were four conditions presented. In the concordant condition the first word biased the meaning of the second homographic word such that it was consistent with the meaning of the third word (e.g., *music-organ-piano*). In the discordant condition, the first word biased the meaning of the second homographic word such that it was inconsistent with the meaning of the third word (e.g., *kidney-organ-piano*). In the neutral condition, the first word was unrelated to the following two words (e.g., *ceiling-organ-piano*). Finally, in the unrelated condition, both the prime words were unrelated to the third word (e.g., *kidney-ceiling-piano*). Schvaneveldt et al. found in a sequential LDT facilitation for the concordant condition compared to the remaining three conditions.<sup>6</sup> More importantly, Schvaneveldt et al. also found that the discordant and unrelated conditions produced relatively equal response latencies with both being slower than the neutral condition. This finding has been viewed as suggesting that the first word biases the meaning selected of the second homographic word. Because in the discordant condition, the meaning of the homographic word is unrelated to the meaning of the third word, response latency to the third word is very similar to an unrelated condition.

The predictions are clear. If the production priming effects reflect meaning-level

<sup>6</sup> Actually, Schvaneveldt et al. referred to their neutral prime condition as a terminal prime condition in which the first word was unrelated to the second and third words and the second and third words were related to each other. Schvaneveldt et al. also included additional control conditions, the results of which suggest that the present four priming conditions are appropriate for the issues being addressed in our study.

influences, then one would expect the same pattern reported by Schvaneveldt et al. in the production duration data. On the other hand, if the production priming effects are simply due to associative cooccurrences of "related" words, then one might expect the discordant condition to be more similar to the neutral condition because in both cases the first word is associatively unrelated to the third word and the second word is associatively related to the third word. Both of these conditions should produce shorter production durations than the unrelated condition, where neither the first nor the second word is associatively related to the third word.

It is noteworthy that subjects pronounced all three words aloud on each trial in Experiment 3. However, in contrast to Experiment 2, only the onset latencies and production durations for the third word are of interest here. Thus, any impact of prime condition on production durations will eliminate the possibility that the results from Experiment 2 were due to priming from the first word to the *onset* of the second word.

In addition to the manipulation of context, Experiment 3 involved two further factors. First, stimuli were repeated across Blocks 1 and 2 and then switched in Block 3 to address repetition effects in onset latencies and production durations. Also, there was a manipulation of the delay interval between the second and the third words to address whether there is any change in the influence of context across these delays. Thus, Experiment 3 was a 3 (Block)  $\times$  2 (250-ms vs 1250-ms delay between the production of the second word and the presentation of the third word)  $\times$  4 (prime condition) within-subjects design.

### Method

**Subjects.** A total of 32 subjects participated in this experiment. Sixteen were students at Washington University and 16 were recruited via local ads.

**Apparatus.** The apparatus was the same

as that used in the previous experiments. The only exception was that the software was modified such that the system considered 236 ms of silence the end of the production instead of the 300-ms limit used in Experiment 2.

**Materials.** The critical stimuli were based on 64 sets of seven words which were based on the stimuli used by Balota (1983). For each set, there was a homographic word (e.g., *organ*), two words related to one meaning of the homograph (e.g., *music* and *piano*), two words related to a different meaning of the homograph (e.g., *kidney* and *heart*), and two unrelated words (e.g., *ceiling* and *world*). One of the related words was designated as the target for a given set of triads. The four conditions created from each set were the concordant (e.g., *music-organ-piano*), the discordant (e.g., *kidney-organ-piano*), the neutral (e.g., *ceiling-organ-piano*), and the unrelated (e.g., *kidney-ceiling-piano*). For the first block of trials, across each group of four subjects a given target was counterbalanced across these four conditions. Also, for the first block of trials, across each subsequent group of four subjects a given target appeared in either the short-delay condition or the long-delay condition. The second block of trials was an exact replication of the first block, including the order of test trials.

The third block of test trials involved switching the conditions for a given group of seven words between the concordant and the discordant conditions and between the neutral and the unrelated conditions. Thus, for example, if the subject received the concordant triad *music-organ-piano* for the first two blocks of trials, then in the third block the subject would receive the discordant triad *music-organ-heart*. Likewise, if the subject received the discordant triad *music-organ-heart* for the first two blocks of trials, then in the third block of trials the subject would receive the concordant triad *music-organ-piano*. The same type of switch across blocks occurred be-

tween the neutral and the unrelated conditions. Because the targets changed across the first two blocks and the third block of trials, the target conditions which occurred for the first two blocks of trials for the first group of 8 subjects were switched to the target conditions for the third block of trials for the next 8 subjects and vice versa. Finally, for 16 subjects, the delay between the second word and the third word was kept constant across the first two and third blocks for a given set of triads, whereas for the remaining 16 subjects, the delay was switched from short to long and vice versa for a given set of triads.

In addition to the critical items, there were 28 triads used for practice trials and 8 used for buffer trials. The same 4 buffer triads served in Blocks 1 and 2, and a different 4 served in Block 3. These practice/buffer triads included no discordant biasing of meanings, but rather included an equal representation of conditions in which (1) the first two words were related to the third, (2) the first word was related and the second word was unrelated to the third, (3) the first word was unrelated and the second word was related to the third, and (4) both words were unrelated to the third.

**Procedure.** The following sequence occurred on each trial: (a) a row of three asterisks separated by blank spaces in the center of the screen for 275 ms; (b) a blank screen for 275 ms; (c) a tone for 250 ms; (d) a blank screen for 275 ms; (e) the first word in the center of the screen; (f) the subject pronounced the first word aloud; (g) 200 ms after the end of the production, the second word appeared on the line immediately below the first word; (h) 200 or 1200 ms after the end of the production of the second word, the first two words were erased; (i) a 50-ms blank screen; (j) the third word on the line immediately below where the second word appeared; (k) the completion of the subject's pronunciation of the third word; (l) a blank screen for 300 ms; (m) the message "IF YOU CORRECTLY PRONOUNCED THE WORDS, PRESS THE

"0" BUTTON, OTHERWISE PRESS THE "1" BUTTON; (n) the subject either pressed the "1" button or the "0" button; (o) a blank screen for the 2-s intertrial interval.

Subjects were instructed to pronounce each of the three words as quickly and as accurately as possible. They received a total of 232 trials: 36 practice/buffer trials and 192 test trials. There were four breaks. One break occurred after the 14th practice trial and the remaining breaks occurred before each test block. All remaining aspects of the experiment were similar to those of the earlier experiments.

## Results

**Onset latencies.** Figure 7 displays the mean onset latencies as a function of prime condition. The major point to note here is that the concordant condition produced faster onset latencies than the remaining three conditions.

The results of the ANOVA yielded a highly significant effect of Prime,  $F(3,93) = 15.90$ ,  $MSe = 422$ . Planned comparisons indicated that the concordant condition was significantly faster than the remaining three conditions and also that the neutral condition was significantly faster than the unrelated condition (all  $ps < .05$ ). This analysis also yielded a main effect of Block,  $F(2,62) = 10.88$ ,  $MSe = 2435$ , that indicated that

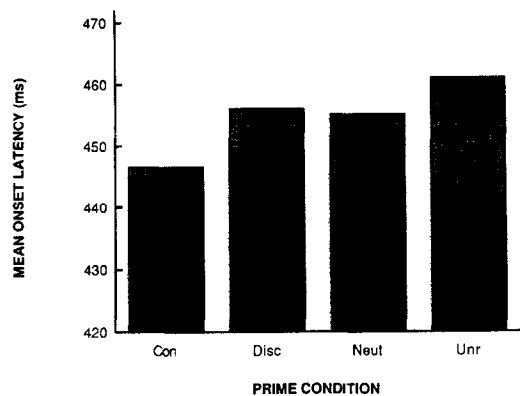


FIG. 7. Mean onset latency for the concordant, discordant, neutral, and unrelated prime conditions.



overall response latency for Block 1 (mean = 461 ms) was slower than that for Block 2 (mean = 443 ms), which in turn was faster than that for Block 3 (mean = 459 ms). This analysis also yielded a significant effect of Delay,  $F(1,31) = 8.75$ ,  $MSe = 1493$ , that indicated that the overall response latency at the short delay was slower (mean = 459 ms) than that at the long delay (mean = 450 ms). The only remaining effect to reach significance in the analysis on the onset latency data was a Block  $\times$  Condition interaction,  $F(6,186) = 2.93$ ,  $MSe = 532$ . Post hoc analyses indicated that this latter interaction was primarily due to the fact that the neutral condition was faster than the unrelated condition in Blocks 1 and 2 but not in Block 3.

**Production durations.** We now turn to the more important production duration data. These data are displayed in Fig. 8. As shown, it appears that the production durations for the concordant and neutral conditions are equivalent and both shorter than the discordant and unrelated conditions. Moreover, the discordant and unrelated conditions appear to produce equivalent production durations.

The ANOVA on the production duration data yielded a significant effect of Prime Condition,  $F(3,93) = 4.15$ ,  $MSe = 366$ .

Planned comparisons indicated that the concordant condition did not differ from the neutral condition, and the discordant condition did not differ from the unrelated condition, both  $ts < 1.00$ . However, the concordant condition produced significantly shorter production durations than both the discordant and the unrelated conditions (both  $ps < .05$ ), and the neutral condition produced significantly shorter production durations than both the discordant ( $p < .05$ , one-tailed) and the unrelated conditions ( $p < .05$ ). The analysis on the production duration data did not yield any other effects that reached significance (all  $Fs < 1.25$ ).

**Percentage correct.** An ANOVA on the percentage correct data yielded only a main effect of Delay,  $F(1,31) = 8.62$ ,  $MSe = .17$ , that indicated that accuracy was slightly higher at the short delay (97%) than at the long delay (96%).

### Discussion

The major results of Experiment 3 are clear. The production durations yielded a significant influence of prime type. Moreover, the pattern of influence was consistent with the interpretation that the present priming results involve a meaning-level influence rather than a simple associative cooccurrence influence. That is, the discordant condition produced longer production durations than the neutral condition but did not differ from the unrelated condition. This pattern would not be predicted if only cooccurrence was producing the obtained effects because in both the discordant and the neutral conditions, the second and third words were related and both were unrelated to the third target word. However, these results are predicted by a meaning-based account of the present results that suggests that the first prime word biased the meaning of the second homographic word that was unrelated to the third target word, thereby producing similar perfor-

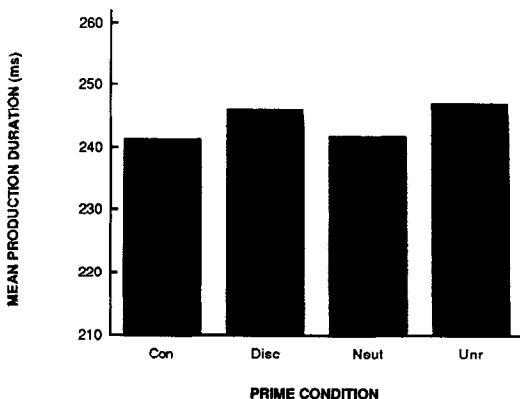


FIG. 8. Mean production durations for the concordant, discordant, neutral, and unrelated prime conditions.

mance in the discordant and unrelated prime conditions.<sup>7</sup>

There are a number of further points that should be noted about the results obtained in Experiment 3. First, although the effects of prime condition on production duration were significant, the size of the effects were quite small, on the order of 6 ms. In this light, it is noteworthy that Balota and Duchek (1988) have replicated this precise pattern with a group of older adults. It should also be noted that there was a considerable amount of power in both the present study and the Balota and Duchek study (1536 observations/prime condition).<sup>8</sup>

Second, the results of Experiment 3 eliminate the possibility that the priming effects found in Experiment 2 were simply due to a decrease in the interword interval between the first word and the second word in the related condition compared to the unrelated condition. If this were the case, then one would not expect an impact of the primes in Experiment 3, where the production durations of only the target items were measured.

### GENERAL DISCUSSION

The major motivation of the present research was to determine whether there are influences of associative relatedness in the production aspects of the pronunciation

task. With respect to this goal, the present results are quite clear. Although there was no impact of relatedness on the onset latencies in the delayed-pronunciation results of Experiment 1, there was evidence of an impact on the production durations. The production durations were shorter when to-be-pronounced words were cued by related words than when they were cued by unrelated words. Because this influence of cue relatedness was relatively restricted in time in Experiment 1, Experiment 2 was conducted to address whether such an effect would be found at relatively longer delays if the relationship between the two words is available throughout the delay period. This was accomplished by simultaneously presenting two words on each trial with the subjects' task to pronounce both words aloud in a delayed-pronunciation task. The results indicated that there was an influence of relatedness on both onset latencies and production durations after subjects had sufficient time to recognize the stimuli. Moreover, a manipulation of preparedness yielded a large impact on onset latencies and a relatively small impact on production durations. Experiment 3 addressed whether the influence of relatedness on production durations was due to simple associative cooccurrence or involved meaning-level relationships between the words. In this experiment, the impact on production durations of a preceding context that disambiguated homographic words was examined. The production results of Experiment 3 indicated that subjects computed the inconsistencies in the meanings selected by the context preceding the homograph and the meaning selected by the target following the homograph. These results were viewed as suggesting that the present production priming results involve meaning-level analyses.

In an attempt to provide a theoretical framework to discuss the influence of relatedness on production durations, we first consider the interactive activation model of

<sup>7</sup> An alternative account of the results of Experiment 3 should be noted. It is possible that homographic words have unique *lexical* entries for each of the underlying meanings (Rubenstein, Lewis, & Rubenstein, 1971). If this were the case, then it is possible to account for the results from Experiment 3 in terms of intralexical priming. Although this alternative is possible, it does seem to blur the distinction between lexical-level and semantic-level representations.

<sup>8</sup> It is noteworthy that in an experiment in which subjects only read the primes silently, there was no impact on production durations. However, because of a number of variations across the experiments (e.g., different SOAs, levels of prime processing, and auditory prime feedback), it is difficult to specify the factor that led to the difference in results.

speech production developed by Dell (1986), and discuss potential constraints that the present data place on this model.<sup>9</sup> After this discussion we consider the present results within a more global theoretical framework that incorporates notions of the cooperative principle in language production.

### *Dell's Interactive Activation System*

Dell's (1986) interactive activation model of speech production has the ability to account for a considerable amount of the speech error data, the major database for models of speech production. Like other interactive activation models (e.g., McClelland & Rumelhart, 1981), Dell's model is a multilevel framework that entails both serial and parallel processing components. The three major levels of processing in Dell's framework are the syntactic level, the morphological level, and the phonological level.

In producing a sentence, one of the first processes completed is the selection of an appropriate syntactic frame. Once this syntactic frame is selected, the components that fit this frame begin to receive activation. For example, if a quantifier is the first constituent of a syntactic frame, then all quantifiers begin to receive activation. As these lexical-level representations receive activation there is also a spread of activation to lower levels in the system such that both the morphemes and the phonemes that are consistent with these quantifiers are also receiving activation. In addition to the spread of activation from higher levels to lower levels, there is also feedback from

the lower levels to consistent higher levels. Thus, once a given phoneme is activated it also begins to activate consistent morphemes which in turn begin to activate corresponding lexical items. The node that has the highest level of activation after a given amount of time has passed is selected for a slot in the current frame. Selection in essence involves tagging that representation for output order. For example, if the word *some* has been selected for the syntactic frame for the production of "Some swimmers sink," then this representation would be tagged "1" for output order.

Dell's framework accounts for speech error data through the activation patterns that converge on a given representation. For example, "Sim swimmers sink" might be produced instead of the intended production "Some swimmers sink" because the phoneme /I/ received substantial activation from both the upcoming words *swimmer* and *sink*. In this case the /I/ phoneme had a higher level of activation at the critical point of tagging than the /A/ phoneme.

Dell also discusses the error in which "The doctor has a new nurse" is produced instead of the intended production "The doctor has a new purse." Presumably, this error would occur because the /n/ phoneme received substantial activation due to both its occurrence in the word *new* and its occurrence in the word *nurse* which is highly related to the word *doctor*. It is important to note here that, according to Dell, the relationship between *nurse* and *doctor* would be a semantic/conceptual influence and not an intralexical impact, consistent with the results from Experiment 3. Obviously, this *purse* to *nurse* error is highly relevant to the present results because it indicates that conceptual relationships can influence the activation levels for phonemes in production.

The major extension that appears necessary for the Dell framework to account for the present production data is that spreading activation influences not only which phonemes are selected but also the *rate* at

<sup>9</sup> Our choice of the Dell framework is based, in part, on its reliance on the interactive activation framework which has also been successfully applied to a number of variables in speech perception (e.g., McClelland & Elman, 1986; Stemberger, 1985). Because one of our interests is in how variables influence both perception and production, this is a positive characteristic. However, the present results could also be discussed within the theoretical frameworks for speech production developed by Bock (1982) and MacKay (1982).

which they are selected. Because Dell was interested in speech error data, he primarily addressed which phonemes are selected as opposed to their rate of selection. The mechanisms for node selection according to Dell's model involve selecting the node that has the highest level of activation after a given amount of time has passed. If threshold levels are specified instead, such that a node would be selected once activation reached a specified level, then such an interactive system would also reflect how quickly phonemes become available in production. Those phonemes that receive higher levels of activation should become available earlier. Furthermore, if one extends this interactive framework to the output motor codes, then once a phoneme becomes available for output, one should also find that the connected motor codes should become available for output. In this way, if there is a conceptual relationship between the context and a to-be-pronounced target word, then one might expect the target to be output more quickly because of the "extra" activation that should spread to the constituent phonemes that correspond to the related target. Such a modification would predict the priming effects found in the production durations of the present experiments.<sup>10</sup>

This account can also handle the obser-

vation that in some conditions there were actually larger impacts of associative relatedness on production durations than on onset latencies (e.g., see the 1900-ms delay condition of Experiment 3). This might be expected because the impact of relatedness on onset latencies would reflect the speed to select only the first phoneme of the production, whereas the impact of relatedness on the production durations would reflect the speed of selecting each of the phonemes in the production of a given word. Thus, any influence of relatedness would summate across the phonemes in production. Of course, there are other factors (e.g., those related to pattern recognition) that could produce different influences of a variable on onset latencies and production durations.

The purpose of this brief discussion of Dell's model is simply to indicate how an interactive framework could account for the production duration results. Although the detailed level of analysis provided by Dell's framework may ultimately provide the most compelling account of the present research, there is a more global-level framework that should also be discussed.

### *The Cooperative Framework*

The cooperative framework in language production involves the notion that in producing a sentence the speaker takes into consideration the listening constraints of the target for the communication (Clark & Clark, 1977; Grice, 1975). This cooperative phenomenon has been well documented in the literature concerning situational variation of conversational style. For example, adults have been shown to slow their rate of speech and use shorter sentences when speaking to young children (Broen, 1972; Remick, 1971; Sachs, Brown, & Salerno, 1976). In addition, children 4 and 5 years of age speak differently to younger children than to children of their own age (de Villiers & de Villiers, 1978; Shatz & Gelman, 1978).

More directly relevant to the present discussion is the interplay that can be seen in

<sup>10</sup> It is important to note that we have been emphasizing that the production priming effects are due to faster sequencing of motor codes in the associatively related conditions; however, because of the equipment utilized it was impossible to discriminate whether the effects were due to a decrease in duration of the target word for the related conditions or to an increase in amplitude and duration in the unrelated conditions caused by the application of greater stress marking. Both relative amplitude and duration are correlates of stress (Liberman, 1960). Clearly, even if future spectrographic analyses indicate that the present results are primarily due to stressing effects this in no way compromises the present conclusion of associative influences in production. At its current stage of development, it is unclear how such stressing effects might be incorporated within Dell's interactive activation framework.

the influence of "given" vs "new" information in speech production. That is, information that is "new" in the sense that it was not presented earlier in a sentence received greater stress than information which provides no "new" information (Fowler & Housum, 1987; Halliday, 1967; Klatt, 1975). This finding fits quite well within the cooperative framework. That is, "new" information is relatively less predictable than "given" information and therefore demands more stimulus information for accurate recognition by the listener. Thus, the speaker obliges this greater need by increasing the stress and duration for "new" information, or by decreasing the relative stress for "given" information.

The cooperative principle may also be extended to the present production duration data. That is, the reason that the duration of related words is shorter than that of unrelated words is because related words are more predictable than unrelated words and therefore need less stimulus information. Because such a constraint is built into the speaker's speech perception system, the speaker utilizes this constraint to modify production durations. This is quite consistent with the research on the "given" vs "new" distinction noted earlier. That is, "given" information is similar to related information in that both are relatively more predictable based on the context than "new" and unrelated information.

A study by Lieberman (1963) is particularly relevant here. Lieberman had subjects produce sentences that contained either a high-predictable target word (e.g., the word "nine" in the sentence "A stitch in time saves nine.") or a low-predictable target word (e.g., the word "nine" in the sentence "The number you will hear is nine."). There were two major findings in the study. First, both the durations and the relative peak amplitudes of the target words were greater when they were preceded by the low-predictable context than when they were preceded by the high-predictable context (also, see Shields & Balota, 1988). Sec-

ond, when the target words were excised from the productions and presented to a second group of subjects for perceptual recognition, subjects were better at recognizing the words that were excised from the low-predictable contexts compared to the high-predictable contexts. Thus, the Lieberman study provides evidence not only that productions are influenced by predictability, but that such influences on productions have the expected impact on speech perception. Such an interplay is clearly predicted by the cooperative principle.

The level of analysis provided by the cooperative framework is far from the analytic level provided by Dell's framework. Obviously, in the present study subjects were not speaking for a listener. Thus, one would need to argue that these "cooperations" are automatically engaged in the speech production system. However, notwithstanding such problems, the cooperative framework does provide some useful insights into the obligatory interactive nature between speaker and listener.

## CONCLUSIONS

The present experiments have begun to address characteristics of the production aspects of simple pronunciation. These experiments have provided evidence regarding variables that have been primarily investigated and viewed as influencing pattern-recognition processes in pronunciation. Although our major interest was in the influence of contextual relatedness, we also provided evidence concerning processes such as homograph disambiguation, preparation, and repetition, along with the time course of such processes. These results clearly suggest that onset latencies are only one component of pronunciation that these variables influence.

Finally, with respect to the major question addressed in the present study, there is clearly an influence of relatedness after subjects have recognized the stimulus in simple pronunciation. Thus, these results are *inconsistent* with the view that after the

pattern is recognized the extra activation that was produced by a related context no longer influences performance. Any such "extra" activation carries throughout the speech production system. These results were interpreted within a highly interactive system that provides multilevel activation patterns from the beginning of stimulus presentation to the output of the last phoneme in production. Now that the basic phenomenon has been documented, future research should address further similarities and dissimilarities in the constraints of the pattern-recognition system and the output system.

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