"Same-Different" Reaction Times to Consonants, Vowels and Syllables*

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It has been proposed that phonetic segments are encoded into perceptual units of syllable size. The aim of this study is to investigate how consonant and vowel information is transmitted (i.e., serial vs. parallel), and to what extent auditory and phonetic levels of analysis may interact in perceptual analysis. Synthetic CV syllables, /ba/, /bae/, /da/, and /dae/, were arranged to produce four types of stimulus pairs: 1) consonant same - vowel same (CS-VS, e.g., /ba/-/ba/), 2) consonant same - vowel different (CS-VD), e.g., /ba/-/bae/, 3) consonant different - vowel same (CD-VS, e.g., /ba/-/da/), and 4) consonant different - vowel different (CD-VD, e.g., /ba/-/dae/). Same-different reaction times (RTs) were obtained separately for consonants, vowels, and syllables. In the consonant and vowel conditions, RTs for "same" responses were faster when the irrelevant feature was the same (i.e., CS-VS); "different" response RTs were faster when the irrelevant feature was different (CD-VD). In the syllable condition, RTs for different responses were faster when the vowel was different and the consonant was the same (i.e., CS-VD) than when the consonant was different and the vowel was the same (i.e., CD-VS). This suggests that vowel information may be more easily accessible for a comparison than consonant information. These results provide evidence for the parallel transmission of information about stop consonants and vowels in syllables, and an interaction of auditory and phonetic levels of processing speech perception.

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What are the basic units of perceptual analysis in speech sound perception? Are they syllables, segments or features? Obviously each of these units is in some sense psychologically "real" since their existence has been verified repeatedly in experiments dealing with speech perception and production. But the important theoretical question now is how are these units represented at various levels of perceptual analysis. It is generally agreed that some units are more abstract than other units although the nature of these arguments have not been detailed very precisely. For example, syllables are usually thought to be less abstract than phonetic segments because they exist as both articulatory and acoustic units. On the other hand, phonetic segments are considered to be more abstract because they are, in general, not directly represented by sound segments in the speech signal.

It has been suggested that the syllable is the carrier of phonetic information and that phonetic segments are encoded into perceptual units of syllable size. Moreover, it has been suggested by a number of investigators that the acoustic information in a syllable is simultaneously providing information about two or more segments at the same time. In other words, there is a form of parallel transmission of information about phonetic

segments encoded in syllables. If this is true then the processing of one phonetic segment may be effected concurrently with the processing of another segment within the same syllable. It follows from this that decisions about specific segments may require the use of information distributed over an entire syllable.

In the present study we were concerned with the way consonant and vowel information is represented within a syllable and the types of decisions that can be made when different levels of perceptual analysis are required. The technique we used to explore this problem was a "same"-"different" reaction time task. On any trial two synthetic CV syllables were presented to a subject and he was required to determine whether the two stimuli were the "same" or "different." Reaction times were obtained under three separate conditions: (1) comparison of syllables, (2) comparison of vowels, and (3) comparison of consonants.

Slide 1 please

Method and Procedure

Slide 1 shows the stimulus conditions used in the present experiment. The cv syllables /ba/, /da/, /bae/ and /dae/ were arranged in all possible pairs to produce four experimental conditions: (1) consonant same - vowel same, (2) consonant same - vowel different, (3) consonant different - vowel same and (4) consonant different - vowel different. The two cells marked with an asterisk, the CS-VS and the CD-VD cells, are completely redundant with the required response. Thus, the CS-VS cell always required a "same" response and CD-VD cell always required a "different" response. Responses

to the other two cells varied depending on whether subjects were comparing syllables, vowels or consonants.

For the syllable condition, Ss were told to respond "same" only if both members of a stimulus pair were identical syllables, they were told to respond "different" if the two syllables differed in any way. For the vowel condition they were told to respond "same" only if the vowels in each syllable were identical and to respond "different" if the vowels were different. They were told to ignore the consonants. Similar instructions were used in the consonant condition. The order of presentation was counterbalanced across six groups of four subjects each. The stimuli were 300 msec. three-formant patterns produced on the synthesizer at Haskins Laboratories. All responses and reaction times were recorded automatically under the control of an IBM 1800 computer. Reaction times were measured from the offset of the last stimulus.

Results and Discussion

A number of very interesting results were obtained in this experiment but because of time limitations we will only describe the major findings and leave some of the finer details for another time.

Slide 2 please

Slide 2 shows the mean reaction times for "Same-Different" responses for each of the three conditions: syllables, vowels and consonants. "Same" responses are faster than "different" responses in each condition. More importantly, however, decisions about syllables are consistently faster than vowels and decisions about vowels are consistently faster than decisions

about consonants. This is true for both "same" and "different" responses. Note in particular that "same" responses to syllables are unusually fast suggesting that this decision may occur even before the second syllable has terminated. Thus, there is a hierarchy in terms of the decision times from syllable to syllable nucleus to consonant. This is not the whole story since in this slide we have collapsed over all "same" and "different" conditions.

Slide 3 please

In this slide we now have the reaction times broken down into the four stimulus conditions. In the syllable condition we can see that "different" responses are ordered systemtically. Reaction time is fastest when both the consonant and vowel differ, somewhat slower when only the vowels differ and slowest when only the consonants differ within a syllable. Thus, it comes as no surprise to find that consonant and vowel information is processed differently even in the syllable condition. But let us move to the data for the vowel and consonant conditions for a moment. Note that the redundant cells, those marked with an asterisk are consistently faster than the non-redundant cells and this is true in both the vowel and consonant conditions. Thus, when a subject is required to compare two vowels in a CV syllable, processing of the consonant apparently interferes with the decision about the vowel. This result is also true when the subject is required to compare only the consonants. Processing of the vowel also interferes with the decision about the consonant. This difference is in the order of about 100 msec. for the "same" responses but only around 30 msec. for the "different"

responses. These findings which are quite similar to Day and Woods' results with an identification paradigm suggest that the acoustic information for the consonant and vowel segments in a CV syllable may be transmitted simultaneous and in parallel. If the information were not transmitted in a parallel form we would not expect differences in consonants to affect the vowel decision and differences in vowels to affect the consonant decision.

How can we summarize these results on reaction time to syllables and segments encoded within syllables? We do not have an exact model worked out yet to handle all these results but we think we have some idea as to what the model might look like.

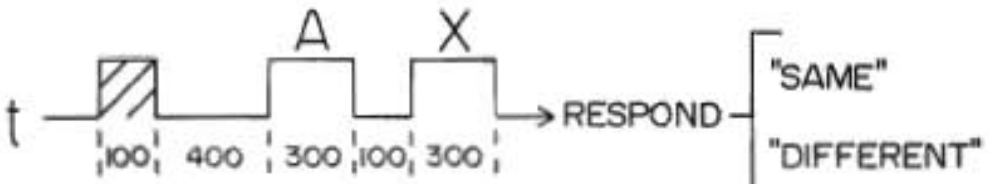
Slide 4 please

In this flow chart we have indicated some of the stages and operations that may be involved in "same"-"different" task. The key to this model is the notion of "depth of processing." We think that the reaction times in the syllable condition can be explained by a relatively simple decision rule at a very early stage of analysis. For example, at Stage 2 the overall gross acoustic similarity of the pair of stimuli is evaluated against a criterion. For the vowel and consonant conditions additional stages and operations must be proposed. We have two explanations for the finding that vowels can be compared more rapidly than consonants. First, the information needed for a decision about the vowels may be more readily available than the information in the consonants. Second, the vowel comparison may take place at an earlier stage of processing than the consonant comparison. Experiments dealing with both possibilities are currently underway at Indiana.

In summary, "same"-"different" reaction times were obtained to pairs of CV syllables. When Ss were required to compare syllables their decisions were faster than when they were required to compare specific segments within syllables. Reaction-time to vowel segments was faster than reaction time to consonants. Moreover, the fact that variations in consonants affect processing of vowels and variations in vowels affect processing of consonants was taken as evidence for the parallel transmission of acoustic information for consonant and vowel segments within syllable sized perceptual units.

STIMULUS CONDITIONS

TIMING:



STIMULI:

/ba/, /da/, /bæ/, /dæ/

EXPERIMENTAL CONDITIONS:

	VOWEL SAME	VOWEL DIFFERENT
CONSONANT SAME	ba-ba da-da bæ-bæ dæ-dæ (CS-VS) *	ba-bæ da-dæ bæ-ba dæ-da (CS-VD)
CONSONANT DIFFERENT	ba-da da-ba bæ-dæ dæ-bæ (CD-VS)	ba-dæ da-bæ bæ-da dæ-ba (CD-VD) *

Figure 1.

MEAN RTs (msec)
"SAME" - "DIFFERENT" RESPONSES
(N = 24 Ss)

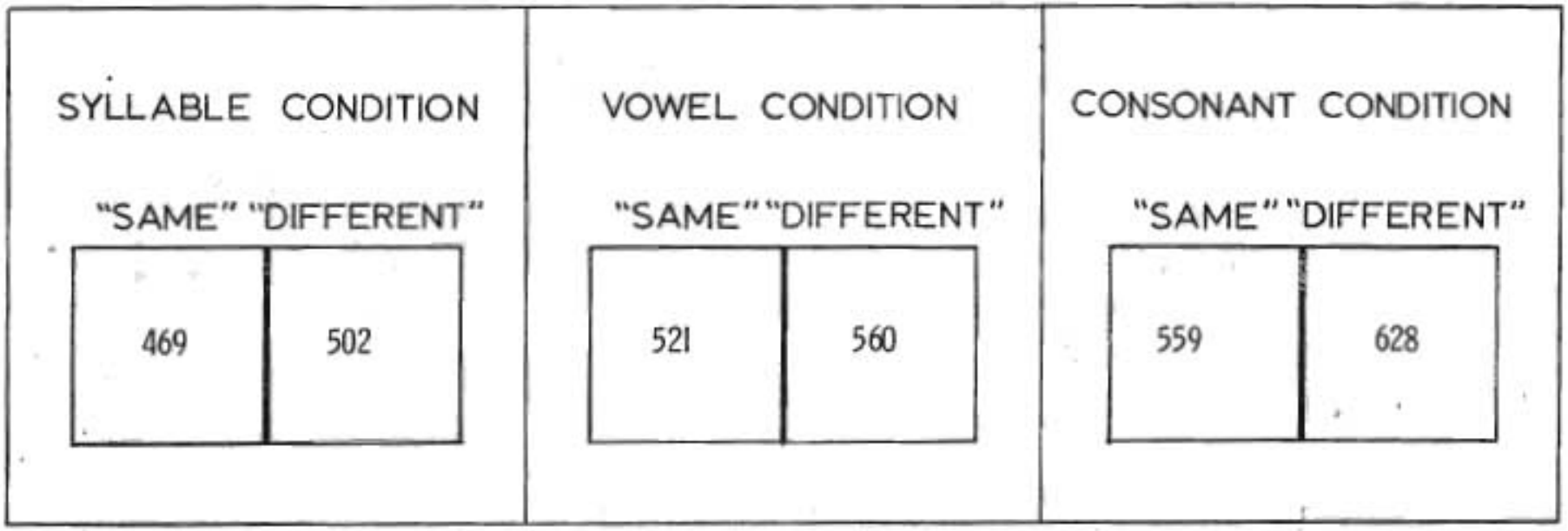


Figure 2.

MEAN RTs (msec)
"SAME" - "DIFFERENT" RESPONSES
(N=24 Ss)

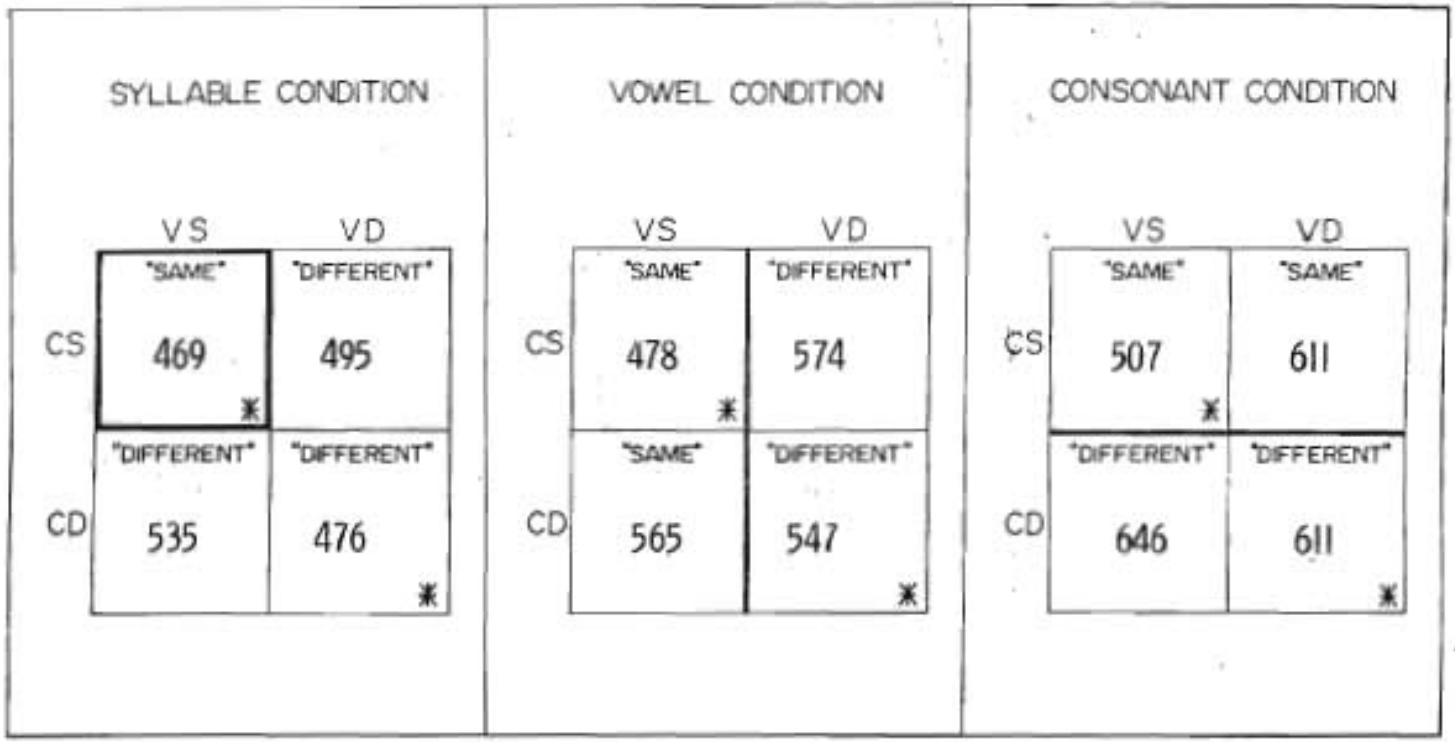


Figure 3.

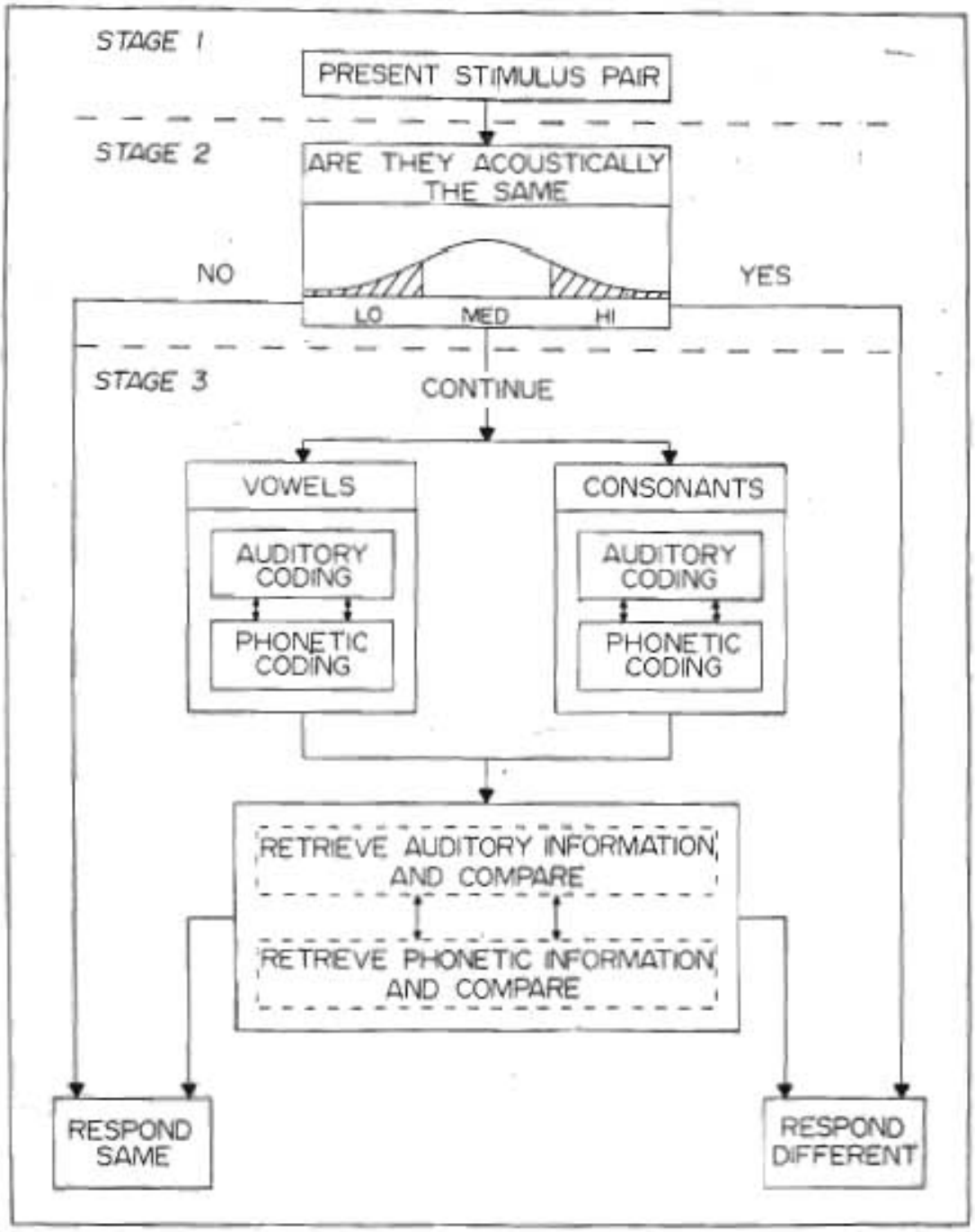

STAGE 1
PRESENT STIMULUS PAIR
STAGE 2
ARE THEY ACOUSTICALLY THE SAME
NO
YES
LO
MED
HI
STAGE 3
CONTINUE
VOWELS
CONSONANTS
AUDITORY CODING
PHONETIC CODING
AUDITORY CODING
PHONETIC CODING
RETRIEVE AUDITORY INFORMATION AND COMPARE
RETRIEVE PHONETIC INFORMATION AND COMPARE
RESPOND SAME
RESPOND DIFFERENT

Figure 4.