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ABSTRACT

This paper examines the validity of the concept of linguistic units in a theory of speech production. Substantiating data are drawn from the study of the speech production process itself. Secondarily, an attempt is made to reconcile the postulation of linguistic units in speech production theory with their apparent absence in the speech signal. (Author/DD)

LINGUISTIC UNITS AND SPEECH PRODUCTION THEORY*

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The first purpose of this paper is to review some kinds of evidence for what I will call the reality status of concepts of linguistic units in a theory of speech production. By this I mean I will review some evidence derived primarily from the study of the speech production process itself, that suggests that the speaker manipulates linguistic units as units when he produces an utterance and some evidence that suggests how he does it. The question of the reality status of units in speech production theory needs to be asked for two reasons. First, it is not at all necessary, a priori, that a postulated linguistic unit of any particular size or type, that has arisen from study of anything other than actual speech production itself is entitled to reality status in the production process. Second, even when considering speech production itself, it is very difficult to find direct evidence for linguistic units because speech is a continually variable output that does not readily lend itself to segmentation, as many phoneticians and engineers have found in the past few years. This lack of direct availability of linguistic units in speech output gives rise to the second purpose of this paper, namely to take some steps towards reconciling the postulation of linguistic units in speech production theory, with their apparent absence in the speech signal.

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One of the problems of studying linguistic units in the speech production process is that we don't have as much experimental control over a speaker's behavior as we do in speech perception studies, where we can manipulate variables related to linguistic units and observe the listener's response to them. This is one reason why we have become heavily dependent on errors in spontaneous output of speakers in our study of production units. I now want to consider some of the information provided by speech errors about linguistic units in speech production. I regret to say that most of the data and interpretation I give here is not from my own work but mainly from two important papers by MacKay (1969) and Fromkin (1971). I regret it because ever since I read Lashley's well known (Lashley, 1951) paper on serial order I have been interested in the contribution that speech errors could make to models of speech production. However, the only sizeable corpus of speech errors that I could discover at that time was a compendium of radio and TV blunders, some of which are quite salacious, entitled "Pardon My Blooper". Although I did write a paper analyzing these errors, I never tried to get it published as I felt I could not find an editor whose estimation of the paper's scientific merit exceeded his sense of propriety. (I suppose I should at least have given it a chance to become an underground classic.) Instead I wrote a paper on typing errors, the data for which was readily available from student's lab reports (MacNeilage, 1964). Unlike Fromkin, I did not have the insight to realize that speech errors occur with sufficient frequency in everyday situations to enable compilation of a large corpus in a short time.

Without further ado, here is an analysis of some of the implications of speech errors for linguistic unit concepts in speech production theory.

Practically every unit of speech that has been postulated by linguists or others seems to have reality status in the speech production process in that they can be substituted, transposed, omitted, or added as a unit in an otherwise correct sequence. The distinctive feature, the phoneme, the syllable, the morpheme and the word all have a claim to reality in this sense.

Speech errors also serve to give information about the inventory of members of any given class of units. For instance, with respect to segments or phonemes, one does not observe diphthongs or affricates splitting into two components, one of which participates in an ordering error, thus suggesting that they are single phonemic units rather than closely associated pairs of units. On the other hand, individual consonants in a consonant cluster sometimes act independently in an ordering error, suggesting that clusters are best regarded as groupings of individual phonemes.

Similarly, postulated distinctive features can be evaluated by noting whether or not their physical correlates are independently variable in an otherwise stable sequence of speech output. In this regard a relatively small number of features such as nasality, voicing and place of articulation, which obviously do have independent control possibilities do sometimes seem to be independently variable. For example, in "Cedars of Lemadon" for "Cedars of Lebanon" (Fromkin, 1971) the nasality feature varies independently.

On the other hand, more abstract features such as coronal, which are not defined in such a way as to allow independent control do not appear to be plausible explanations for errors.

Larger units also participate in speech errors as units. Examples are:

a. Words: A lot of bridge has passed under the water since then.

b. Syllables: "opacity and specifity" for "opacity and specificity" (Fromkin, 1971).

Another sense in which units larger than the distinctive feature and phoneme can be said to have reality is that they place strong constraints on the positional privileges governing phoneme or feature errors. Prevocalic consonants, vocalic nuclei (vowels), and post-vocalic consonants rarely occur erroneously other than in the same syllable positions that they originated in.

A schematic view of the speech production process incorporating these facts as well as a number of other implications of speech errors is shown in the first slide.[1] The box at the top requires little discussion. It recognizes the necessity of an initial idea, plan, or intention which is preverbal and is typically though not always, "satisfied" by production of a particular sentence.

The intention must include some semantic information to be made more specific in the formation of a sentence. The next step may be to decide on the general syntactic form of the utterance, at least to a point sufficient to allow the generation of

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[1]This figure comes from MacNeilage and MacNeilage, 1973.

the overall form of the sentence intonation contour. For example, a choice may be made of "I'll have a steak" and not "A steak for me," so that the main sentence stress is assigned to the last word in the sentence. Following this, there may be two parallel operations, the generation of the sentence intonation contour, and the selection of appropriate lexical items with their associated stress patterns. Some characteristics of the lexical selection process are indicated by speech errors reported by Fromkin. One possibility is a "semantic" error, e.g. "hate" for "like", which appears to involve selection of the wrong value for a semantic feature and a following lookup at a wrong lexical address (Fromkin, 1971). A second class of error, e.g. "pressure" for "present", appears to involve selection of a wrong lexical item phonetically "near" the correct one in the lexical storage system (Fromkin, 1971).

I have to confess I don't know very much about the stages of production I have been talking about so far and no doubt this part of the model could be considerably improved. I have included it largely to get us to the next stage where speech error data begin to provide some more obvious constraints on the form of the model, from my point of view. It is necessary to have a buffer, or temporary storage stage, in which a number of lexical items and a sentence intonation contour can coexist, for a number of reasons. First, it is necessary to have a number of words available simultaneously to account for transpositions of words, as Lashley initially pointed out. In one of Fromkin's examples a "computer in our own laboratory" becomes "a laboratory in our own computer." Second, it is necessary for these transpositions to take place before the assignment of the sentence intonation contour as evidenced by the fact that whereas in the example I just cited the correct version would have a major sentence stress on the first syllable of "laboratory," the transposed version received major sentence stress on the second syllable of "computer". Blends may be accounted for by a selection of parts of two lexical items which were simultaneously available, in temporary store, probably because a definite choice could not be made between them at the previous lexical item assignment stage to fill one lexical slot. The blend "grisp" which was derived from "grip" and "grasp" is an example of this. The items in this store must have at least the syllabic position of the main lexical stress already assigned, otherwise it would not be possible for the sentence stress to fall on the appropriate most highly stressed syllable of the lexical item, as we observed in "computer" where stress is on the second syllable even though the stress for laboratory would have been on the first. For stress to be assigned, syllable structure must also have been specified prior to that point, as the syllable is the domain of stress. At this point, although lexical items are specified as units, there remains some "fluidity" in the linkages within lexical items, such that syllables, phonemes, and distinctive features are in some sense separately available for selection, thus allowing the transposition of syllables, phonemes, and distinctive features which takes place in speech errors.

The next step may be the serially ordered removal of items from the buffer by a scanning mechanism, as proposed by Lashley. This mechanism probably imposes a particular speaking rate on the output. This may result in the transfer of the items to a stage of morphophonemic and phonological monitoring. We know that the scanning mechanism is susceptible to being "confused" in its serial selection of simultaneously available material both by stress values assigned to syllables and by segmental properties, and these variables seem to be the main source of serial ordering errors at the phonetic level (MacKay, 1970). Segment or feature reversals typically involve similar segments and the reversed pair is often preceded or followed by an identical phoneme which seems to have a "triggering" role. Components of stressed syllables are especially likely to participate in reversals, which suggests that the components being advanced in the order are in some way especially salient to the scanning mechanism. One reason for postulating a buffer store of finite size is to account for the inclusion of the delayed component in the spoonerism. If it is in a buffer, it would presumably remain available for selection by the scanner when it comes to the point when it requires the unit that has already been advanced.

It is necessary to postulate the morphophonemic and phonological monitoring stage <u>following</u> the serialization produced by the scanning mechanism, because there are available numerous instances that suggest that <u>after</u> a transposition has occurred, morphophonemic and phonotactic rules renormalize the sequence. It is very rare that even an erroneous output sequence violates either of these two types of rules. As an example of morphophonemic rule operation, consider Fromkin's example of "a kice ream cone" for "an ice cream cone," where the form of the indefinite article in the erroneous phrase is changed,obviously to fit the form of the new initial segment of the next word.

In Fromkin's example of "flay the pictor" for "play the victor," a phonotactic rule apparently devoices the transposed /v/ (giving /f/) after the transposition, as /vl/ is not a permissible sequence in English.

The last three stages in the model will be discussed later in the paper. All ordering errors are deemed to occur before the operation of the target specification mechanism. They certainly occur before the motor control mechanism, because it apparently operates efficiently to produce the movements appropriate to the sequencing of the units, showing that the sequencing, although wrong, is fully specified before the motor control mechanism is activated. The point here is that the specification of the appropriate movements for a segment must follow the ordering decision, otherwise the production, for a segment, of movements appropriate to its old context, would seldom result in its acceptable production.

This is obviously a grossly oversimplified model of the speech production process. For example, it completely omits certain questions such as the status of affixes and the question of whether the segmental consequences of lexical stress are assigned by rule or stored. I present it only in order to give some approximation to the stages involved in the speech production process and to summarize some of the error types, and arguments that have been put forth for the reality status of the various units in speech production theory.

The stages of the mechanism discussed so far (that is down to the morphological and phonological monitor) serve the purpose of providing a subset of linguistic forms with an assigned serial order for an utterance whether right or wrong. The final stage of speech production which I will call the peripheral stage is the conversion of this output into a patterned, time-extended acoustic signal. Perhaps the main thing we have learned about this stage in the last ten years or so is that it is not a good place to look for evidence about the identity and nature of linguistic units. Much of recent phonetic history is a rather melancholy progression of failures to find peripheral correlates of linguistic units. Casualties have included the syllabic chest pulse (Stetson, 1951; Ladefoged, Draper, Whitteridge, 1958), invariant motor correlates of the phoneme (Liberman, Cooper, Harris, MacNeilage and Studdert-Kennedy, 1967; MacNeilage, 1970), the archetypal breath group (Lieberman, 1967; Ohala, 1970) and most recently, coarticulatory marking of syllable boundaries (MacNeilage, 1972). Perhaps all of these related blind alleys needed to be explored. And perhaps there will be more of them, reflecting our bondage to the a priori necessity of thinking about language and speech in terms of linguistic units. But one thing I think our failure should tell us is that it may be time to consider the peripheral stage primarily in terms of its own dynamic properties rather than in terms of abstract linguistic units. The search for invariants has told us at least that linguistic units do not reach output without considerable modification. What is the nature of this modification? Hockett (1955) has suggested a model, and it is the appropriate time of the year to show the input to his model on the next slide. This is a set of variously colored but not boiled Easter eggs, representing segments which are the input to Hockett's model. According to Hockett the output modification of these segments is analagous to forcing them through a wringer in the correct order. Some may favor this as a working hypothesis. But the wringer did not even survive in washing machine technology so it would be embarrassing if it had to carry a heavy theoretical burden in phonetics (not to mention the problem of the speaker having egg on his face). Although it is not yet possible to describe the peripheral stage of the production process accurately with an analogy comparable in vividness and mnemonic value to Hockett's I would like to suggest an alternative view of segmental aspects of the process that at least incorporates more of what we know about the peripheral stage than Hockett's. The central question we are concerned with is: Given that there is a discrete linguistic input to the mechanism of speech production at some stage, and given that the mechanism that transmits this input is incapable of discrete units of output, what is the nature of the transformation, at the peripheral stage, of one form to the other.

The main reason that there is no simple 1:1 correspondence between segments or features and speech signals is because articulators, on whose position the segmental or feature information depends, move relatively slowly from one required quasistationary state to another so that segment-related signals are always contingent on their immediate segmental contexts. Furthermore, we know that this immediate context effect can stretch at least as far as four segments in each "direction" (MacNeilage, 1972). This context dependence is one of the two most central facts about the lack of invariant peripheral correlates of the segment or the features and the principles by which it is controlled must be taken into account in any satisfactory speech production theory. This is the main reason why a theory based on invariant motor commands for segment types of features is unsatisfactory; namely, because it postulates the inverse of what is typically observed. The second central fact about the status of segments at the periphery is that despite this context dependence, articulators typically approximate a single quasi-stationary state for a given segment, regardless of segmental contexts, at least in careful speech. This fact has given rise to a number of theories that what is invariant in the peripheral stage of segment production is the specification of targets or configurational goals towards which the articulators strive (MacNeilage, 1970). A target theory thus has the advantage of preserving an invariant segment or feature-related input to the model while not being inconsistent with the variance in the output. I also think that targets have reality status as means of interfacing the invariant linguistic unit level with the context dependent level in a way that phonemes and features don't. That is, they are consistent with what we know about how the brain works (MacNeilage, 1970). Unfortunately, like phonemes and features, targets are not directly observable. Even in careful speech, articulators do not seem to reach exactly the same place for a segment regardless of context. (They are typically characterized by undershoot.) In most target or configurational theories, this undershoot is attributed to the sluggishness of the peripheral mechanical system and even to the inability to deliver neural signals rapidly enough. At best, this is an oversimplified explanation. That this is so can be seen from an examination of some aspects of segmental dynamics. One fact that has been known for a long time is that when speaking rate is increased the duration of vowels decreases proportionately more than consonants (Chistovich, et al; 1965). It seems to me that, according to a simple neuromechanical inertia model, consonants should decrease in terms of articulation time as much as vowels. But they don't, and I wish to suggest that the reason that they don't is that if they did, it would result in a much greater decrease in the amount of segmental acoustic information available from consonants than from vowels. It is known that consonants carry a greater information load at the segmental level than vowels, at least in English (Denes, 1963). It is also known that in the case of vowels, decreases in duration due to speaking rate increases result in progressively more undershoot of hypothetical target values inferred from careful speech (Moll and Shriner, 1967). It is therefore natural to suppose that if the articulation of consonants followed the same rules as the articulation of vowels, the increased rate would result in increased undershoot. However, whereas increases in amount of undershoot result in only quantitative changes in the acoustic signal for vowels - namely changes in formant frequencies - increases in undershoot could result in qualitative changes in the signal for consonants and these changes might sometimes great enough to make the consonant apparently shift its manner class which could be highly misleading to the listener. For example, an undershot stop might generate friction and undershot fricatives might appear as stops if voiceless and glides if voiced. For this perceptual reason; that is, because of the reception problems that would result from consonants behaving like vowels with rate increase, the production system may impose more restraint on undershoot in consonants than in vowels. If true, this suggests that undershoot is not simply a result of built-in neuromechanical inertia of the peripheral system but, at least to some extent, contingent on the degree of temporo-spatial control chosen by the production system.

In fact it is quite possible that none of the undershoot we see is due to a neuromechanical ceiling effect. Rather, the production system may simply be taking advantage of the demonstrated capacity of the perceptual system to extrapolate from the acoustical correlates of undershoot when it needs to decode the segmental structure of the message (Lindblom and Studdert-Kennedy, 1967).

I would like to describe the constraints on vowels and consonants that I have just discussed in terms of the concept of Tolerance Rules. I would like to suggest that along with target specifications for vowels and consonants the production system specifies tolerances allowed in the approximation to these targets, and that these tolerances are less generous for consonants than for vowels. The concept of tolerance rules has at least been hinted at in some speech synthesis models, and has some affinity to Stevens' ideas about the quantal nature of speech (Stevens, 1972). He has suggested that languages choose segments, the articulation of which allows maximal tolerance, in that the undesirable acoustical consequences of imprecise articulation are relatively minor. This can be, in some sense, viewed as a diachronic view of tolerances. I am suggesting that tolerances for consonants are in general less than those for vowels and that this fact is represented synchronically in the means of control of articulation, and particularly in segment duration rules.

Some evidence that is available about rates of articulator movement suggest that at least with regard to speaking rate these proposed tolerance rules are formulated primarily in terms of time constraints on segment durations, rather than in terms of movement-rate constraints. Studies of articulators during what I would class as a movement from one target to another suggest that when speaking rate increases there is proportionately more change in the duration of a movement than of its average velocity (MacNeilage and DeClerk, 1968). Furthermore, I am not aware of any good evidence that rates of articulator movement are in general greater in movements from vowel to consonant than from consonant to vowel targets.

It does seem to be true that there are differences in rates of articulator movement associated with different consonantal categories. A number of people have shown that the lip-jaw complex moves at a faster rate from vowels to voiceless bilabial stops than to voiced (MacNeilage, 1972). There is also some evidence that rate of articulator movement from vowels to fricatives is slower than to stops (Kim, 1972; Kent and Moll, 1972). It is possible that these differences are due, in the case of stop consonant voicing to 'compensation' for differences in aerodynamic forces against the area of occlusion (Öhman, 1967) and in the case of the fricative-stop difference, the necessity for greater precision of articulator positioning to produce adequate frication (Stevens and House, 1963). If so, then these appear to be cases where differences in tolerance values do affect rates of articulator movement. It is of interest in the light of what I said about time tolerances being greater for vowels than consonants that the 'price' the system pays in time for the slower movement rates for approaches to voiced stops and fricatives is apparently paid by the vowel. This is especially well established, in several languages, for the voicing related difference in vowel duration preceding stops (Chen, 1970).

One reason for arguing that there are rather strict time-tolerance rules for consonants comes from a study that Jaemin Kim and I have done on durations of occlusion of intervocalic stop consonants in citation form as a function of the degree of openness of the adjacent vowels (Kim and MacNeilage, 1972). Slide 3 shows the results of this study in terms of closure durations of 8 subjects. It seems quite clear from these results that the distance from target-to-target either in the VC or the CV transition had negligible effects on duration of occlusion.

The main advantage of a system that has segment-specific tolerance rules for duration of activation of articulators moving toward targets is that it makes possible the kind of versatile "digital-to-analog" conversion that appears to occur in the periphery (using this analogy loosely). It appears that the input must be in terms of invariants, and I am guessing that these are targets. We know the output is characterized by its variability and I suspect that simple time-related neuromuscular ceiling effects aren't the cause. I am suggesting that the variability in target approximation is due to tolerance rules that have a base value for individual segments in careful speech and differing constants proportional to their base value that can produce a continuum of 'degradation' for each sentence as targeting demands are decreased. Thus speaking rate can assume a number of values on a continuum, and given this input, the tolerance constants of segments give as output their corresponding values of approximation to target.[2] For example, Kim has observed that fricatives reduce in duration less in unstressed syllables, relative to stressed, than stops, suggesting that they have more restrictive tolerance rules (Kim, 1972).

Despite the problems that I know it has, thinking in terms of targets and tolerance rules may be a way of coming to grips with the invariance paradox at the necessary level, namely at the level of articulatory dynamics. One thing it offers is a way

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[2]Related rules may apply to stress in English but in this case rate of articulator movement may be more variable than with speaking rate changes.

of coming to grips with the whole range of real speech behavior, including style shifting, and not just with citation form speech.

I will conclude by summarizing the message. Although we must acknowledge the relevance of various linguistic units for speech production theory and strive to learn more about them, we can't afford to stop there. Instead we must try to integrate ideas about linguistic units with hypotheses based on the dynamic properties of the peripheral system, and a conceptual schema based on targets and tolerance rules is an attempt in that direction. Finally, I hope you haven't found this paper to be characterized by the misprinted phrase in the printed abstract of the paper which says "A speaker's output is a continuous strain."

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REFERENCES

1. Chen, M. Vowel length variation as a function of the voicing of the consonant environment. Phonetica, 1970, 22, 129-59.

2. Chistovich, L., et al. Rech: Artikulyatsiya i Vospriyatiye (Speech: Articulation and perception). Moscow-Leningrad: Nauka, 1965. (Translation available from the Joint Publications Research Service, United States Department of Commerce, Washington, D. C., No. 30,543.)

3. Denes, P. B. On the statistics of spoken English. Journal of the Acoustical Society of America, 1963, 35, 892-904.

4. Fromkin, V. A. The non-anomalous nature of anomalous utterances. Language, 1970, 47, 27-52.

5. Hockett, C. F. A manual of phonology. In, International journal of American linguistics (Memoir II). Baltimore: Waverly Press, 1955.

6. Kent, R. D. and Moll, K. L. Cinefluorographic analysis of selected lingual consonants. Journal of Speech and Hearing Research, 1972, 15, 453-473.

7. Kim, J. Studies of Segmental Articulatory Dynamics. Unpublished Ph.D. dissertation, The University of Texas at Austin, 1972.

8. Kim, J. and MacNeilage, P. F. Voiceless consonant durations in VCV utterances. Paper presented at the 85th meeting of the Acoustical Society of America, Miami, Florida, November, 1972.

9. Ladefoged, P., Draper, M. H. and Whitteridge, D. Syllables and stress. Miscellanea Phonetica, 1958, 3, 1-14.

10. Lashley, K. S. The problem of serial order in behavior. In L. A. Jeffress (Ed.), Cerebral mechanisms in behavior (the Hixon symposium). New York: Wiley, 1951.

11. Liberman, A. M.; Cooper, F. S.; Harris, K. S.; MacNeilage, P. F. and Studdert-Kennedy, M. G. Some observations on a model for speech perception. In W. Wathen-Dunn (ed.), Models for the perception of speech and visual form. Cambridge, Massachusetts: M.I.T. Press, 1967.

12. Lieberman, P. Intonation, Perception, and Language. Cambridge: The M.I.T. Press, Research Monograph No. 38, 1967.

13. Lindblom, B. E. F. and Studdert-Kennedy, M. G. On the role of formant transitions in vowel recognition. Journal of the Acoustic Society of America, 1967, 42, 830-843.

14. MacKay, D. G. Spoonerisms: The structure of errors in the serial ordering of speech. Neuropsychologia, 1970, 8, 323-350.

15. MacNeilage, P. F. Typing errors as clues to serial ordering mechanisms in language behavior. Language and Speech, 1964, 7, 144-159.

16. MacNeilage, P. F. Motor control of serial ordering of speech. Psych. Rev., 1970, 77, 182-196.

17. MacNeilage, P. F. Speech Physiology. In J. Gilbert (ed.), Speech and Cortical Functioning, New York: Academic Press, 1972.

18. MacNeilage, P. F. and DeClerk, J. L. On the motor control of coarticulation in CVC monosyllables. J. Acoust. Soc. Amer., 1969, 45, 1217-1233.

19. MacNeilage, P. F., and MacNeilage, L. A. Central Processes Controlling Speech Production During Sleep and Waking. In McGuigan, F. J., and Schoonover, R. A. (eds.), The Psychophysiology of Thinking, New York: Academic Press, 1973.

20. Moll, K. L. and Shriner, T. H. Preliminary investigation of a new concept of velar activity during speech. The Cleft Palate Journal, 1967, 4, 58-69.

21. Ohala, J. J. Aspects of the control and production of speech. UCLA Working Papers in Phonetics, 1970, 15.

22. Öhman, S. E. G. Peripheral motor commands in labial articulation. STL-QPSR 4/1967. Royal Institute of Technology, Stockholm, Sweden, 30-63.

23. Stetson, R. H. Motor Phonetics. Amsterdam: North-Holland Publishing Co., 1951.

24. Stevens, K. N. The Quantal Nature of Speech: Evidence from Articulatory-Acoustic Data. In, E. E. David and P. B. Denes (eds.), Human Communication: A Unified View. New York: McGraw-Hill, 1972.

25. Stevens, K. N. and House, A. S. Perturbation of vowel articulation by consonantal context: an acoustical study. J. Speech and Hearing Res., 1963, 6, 111-128.

Slide Captions

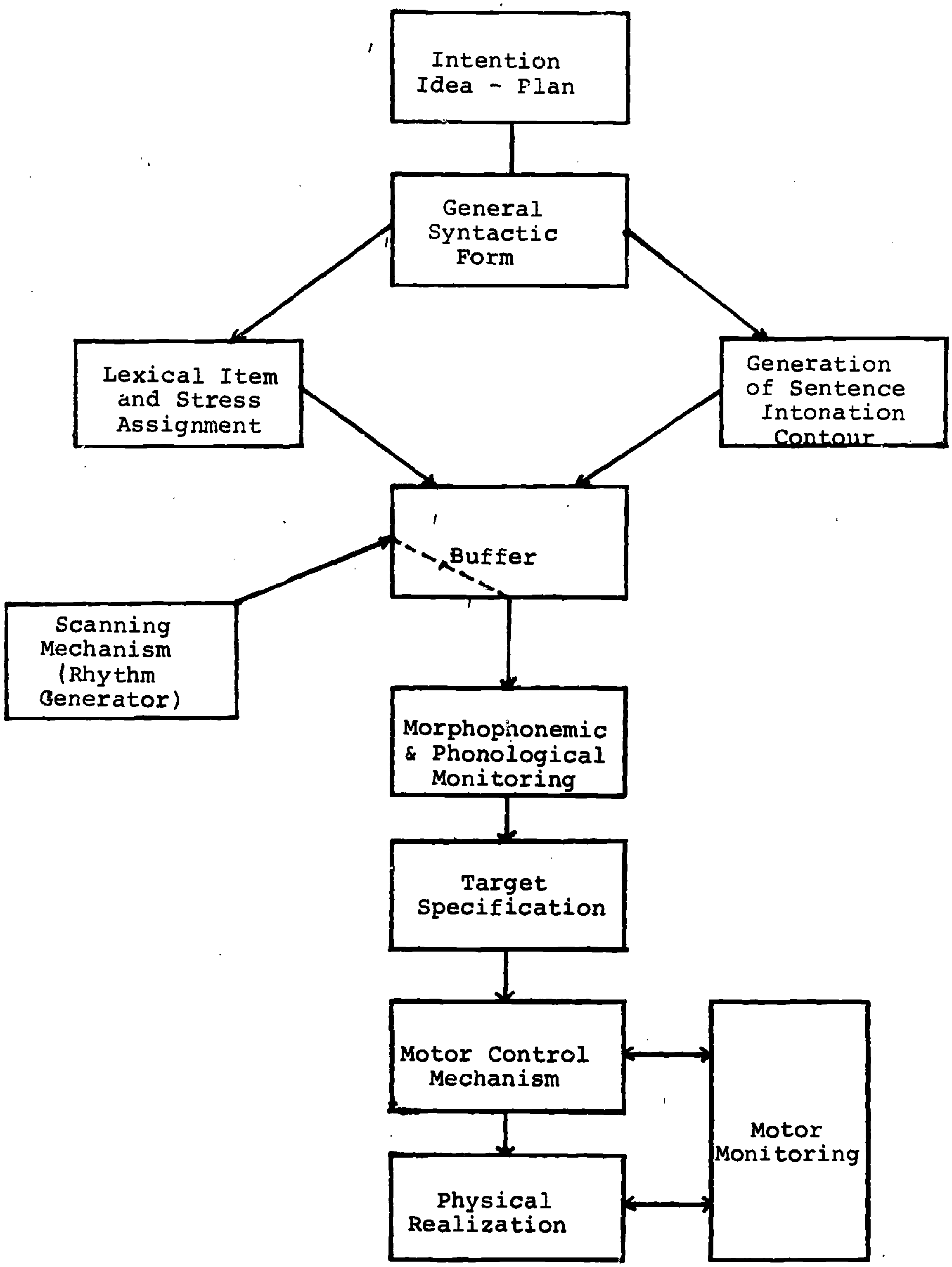
Slide 1: Schematic view of the organization of speech production. (From MacNeilage and MacNeilage, 1973.)

Slide 2: (Not reproduced here.) Multicolored easter eggs.

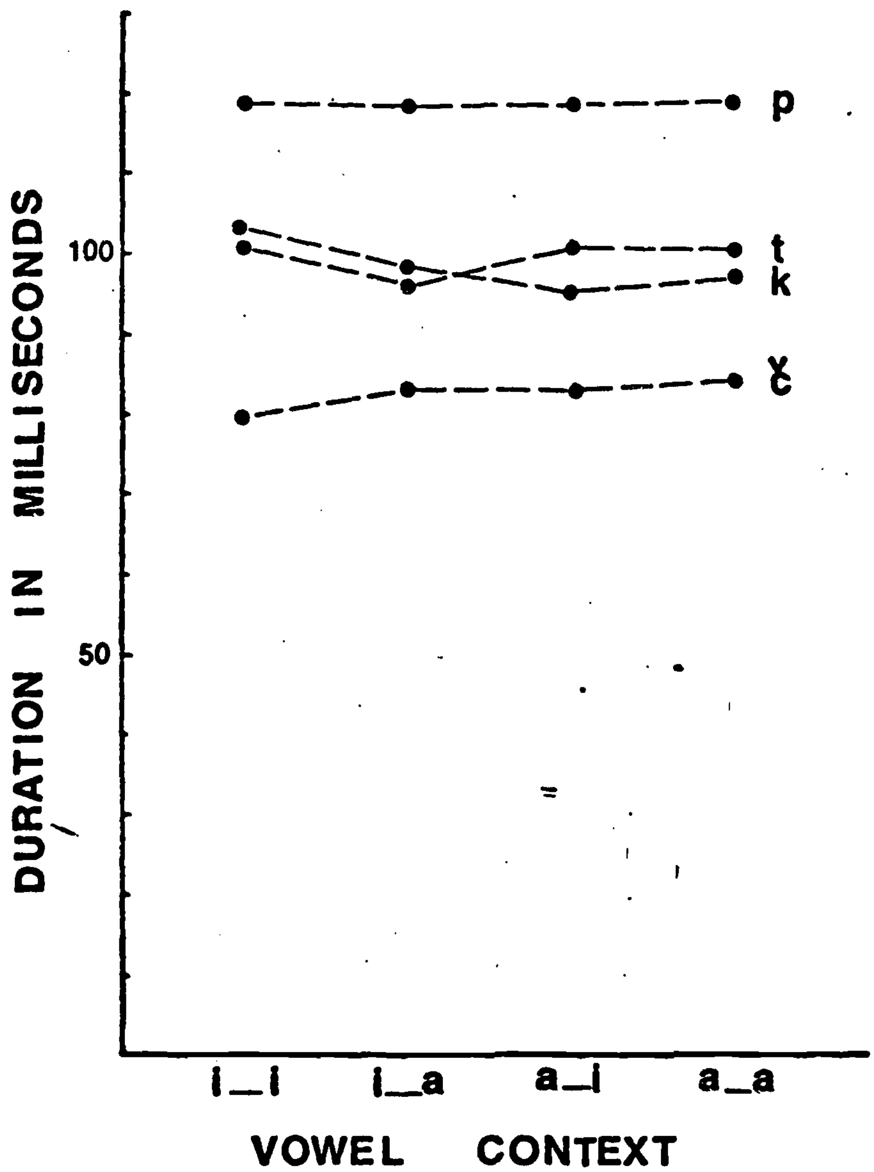
Slide 3: Average durations of consonantal occlusion for 8 subjects produced four consonants in four intervocalic environments. (From Kim, 1972.)

SLIDE 1

SCHEMATIC VIEW OF THE ORGANIZATION OF SPEECH PRODUCTION



SLIDE 3



DURATION IN MILLISECONDS
100
50
p
t
k
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i_i
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a_i
a_a
VOWEL CONTEXT