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The similarity between the antecedents of listening and the consequences of speaking have long led theorists to believe in their intimate and even natural relationship. A tendency to conflate the two processes is found in articles on speech communication, automatic speech recognition, foreign language learning, and child language. Once this scattered literature is assembled and organized, it becomes clear that the present emphasis is on conflation whereas the evidence in each of the four areas favors a more balanced view. Properties of phoneme perception, for example, are often explained in terms of phoneme production, whereas these properties seem to recur in other kinds of perception, unrelated to articulation. At the suprasegmental level, the view that the listener refers what he hears to how he would say it is opposed by the different dynamic characteristics of speaking and listening, which are evident whenever a speaker adjusts his level to match a numerical or acoustic criterion, or to compensate for changes in sidetone, or to maintain intelligibility despite increasing noise. When the relations between speaking and listening are altered by pathology, case studies find further evidence for their relative independence in the normal individual. (Author/JD)

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The similarity between the antecedents of listening and the consequences of speaking have long led theorists to believe in their intimate and even natural relationship. A tendency to conflate the two processes is found in articles on speech communication, automatic speech recognition, foreign language learning, and child language. Once this scattered literature is assembled and organized, it becomes clear that the present emphasis is on conflation whereas the evidence in each of the four areas favors a more balanced view. Properties of phoneme perception, for example, are often explained in terms of phoneme production, whereas these properties seem to recur in other kinds of perception, unrelated to articulation. At the suprasegmental level, the view that the listener refers what he hears to how he would say it is opposed by the different dynamic characteristics of speaking and listening, which are evident whenever a speaker adjusts his level to match a numerical or acoustic criterion, or to compensate for changes in sidetone, or to maintain intelligibility despite increasing noise. When the relations between speaking and listening are altered by pathology, case studies find further evidence for their relative independence in the normal individual.

Some early thoughts on the relation of speaking to listening are as follows:

"Lastly, I am to take notice that there is so great a communication and correspondency between the nerves of the Ear and those of the Larynx that whensoever any sound agitates the Brain, there flow immediately spirits towards the muscles of the Larynx, which duely dispose them to form a sound altogether like that which was just now striking the Brain.... It will come to pass that the Brain, which thereby is often shaken in the same places, sends such a plenty of spirits through the nerves that are inserted in the muscles of the throat that at length they easily move all the cartileges which serve for that action, as 'tis requisite they should be moved to form sounds like those that have shaken the Brain."

De Cordemoy, who wrote these words in 1668[1], may have been the first man to conflate the processes of listening and speaking; he certainly was not the last. It is evident that speaking and listening are related but distinct processes, and that an adequate theory of language behavior must take this into account. Nevertheless, most theories give great weight to the presumptive similarities between uttering speech and listening to it, while giving little weight to their differences. Perhaps this article will help to redress the balance by assembling the scattered literature which illustrates how one-sided our view has become.

Where Conflation Occurs

The view that listening involves speaking, or that speaking involves listening, is prominent in such diverse areas as speech communication, at both segmental and suprasegmental levels, automatic speech recognition, foreign language learning, and child language.

Speech Communication (Segmental Level)

> "The hearer matches the acoustic stimuli he receives against his own habits of muscular speech action, and identifies the incoming sound as corresponding to this or that of his own speech articulations. At both ends of a speech transmission, it is the muscular activity, not the acoustic character, which dominates the identification." (p. 609)

Thus wrote Twaddell in 1952 and Hockett reasoned similarly in his Manual of Phonology, 1955:

> "We may suspect that Jack's speech transmitter is not completely quiescent just because at the moment he is broadcasting nothing. As he listens to Jill, his Speech Receiver is able to decode the signal partly because the incoming signal is constantly compared with the articulatory motions which Jack himself would have to make in order to produce an acoustically comparable signal." (p. 7)

In short: speech is perceived by reference to articulation. Such is also the thrust of Liberman's review of research on speech perception carried out at the Haskins Laboratories: "...articulatory movements and their sensory effect," he wrote, "mediate between the acoustic stimulus and the event we call perception."[2]

Delattre reached a similar conclusion in his survey of the acoustic correlates of consonants and vowels:

> "...s'il existe un invariant qui permette de distinguer un lieu d'articulation consonantique d'un autre, il est plutôt dans le geste articulatoire que dans le trait acoustique: la forme acoustique de la parole serait perçue, non directement, mais indirectement par référence au geste articulatoire qui est le même pour plusieurs valeurs acoustiques différentes."[3]

This point of view encompasses not only vowels and consonants; other investigators contend that reference to articulation is similarly required for the perception of suprasegmental features. "Accent is sui generis depending for its perception on the kinesthetic sense," Jones wrote in 1932. "The listener refers what he hears to how he would say it. Thus he translates exteroceptor into proprioceptor sensations, the kinesthetic memory serving as stimulus." (p. 74)

Ladefoged, Draper, and Whitteridge examined this claim in several electromyographic studies that led them to conclude as follows in 1958:

> "[Statements about stress] are usually best regarded as statements about the speaker's muscular behavior (or about the actions of the listener's muscles which would have to be made in order to produce similar sounds)."[4]

Fónagy (1966) similarly favors a motor theory of stress perception, citing the concurrence of Daniel Jones (1950), Stetson (1951), Schmitt (1924), Laziczius (1961), Lehiste and Peterson (1959), and Jespersen (1932) whom he considers to be the first to state the position, as follows:

> "The hearer identifies himself with the speaker. As he generally perceives the utterance by a silent coarticulation of the sounds uttered (slightly innervating his speech organs) he is founding his estimate of intensity of each syllable on the effort spent on its production."[5]

The motor theory applies not only to the perception of contrastive stress in a complete utterance. Going beyond the reference to articulation for the resolution of phonemic contrasts, Ladefoged and McKinney (1963) suggest that "the perceived loudness of [all] words which are within the normal speech range is largely dependent on...the physiological effort required to produce them." (p. 459)

As in the case of loudness and stress, it has been contended that production enters into the perception of pitch and intonation. Galunov and Chistovich, in their 1966 review of the motor theory, find that the results of studies on pitch matching by Leont'ev (1959) give "conclusive demonstrations of the significance of the motor representation of signals for their evaluation." (p. 361)

Thurlow (1963) addressing himself to the problem of the "missing fundamental," (a complex tone has a pitch corresponding to its fundamental even if the latter is suppressed) believes it is not missing at all: listeners covertly match the tones with phonation, then judge their own fundamental.

The theme of analysis by synthesis is recurrent, too, in Lieberman's recent monograph on "Intonation, perception and language." Listeners often seem to perceive intonation and stress by means of a process of analysis-by-synthesis," he writes, "in which they make use of their knowledge of the articulatory gestures that are involved in the production of speech."[6]

Automatic Speech Recognition

Analysis-by-synthesis is not only the hypothesized recognition process in the listener, it is also the actual recognition strategy incorporated in some recent approaches to automatic speech recognition.[7] Whatever the merits of a motor theory of speech perception, the proposed strategy for mechanical recognition has the advantage that the prohibitively large dictionary of stored patterns required in a passive device whose capabilities approached those of a human listener is not required in the active device, since generative rules are stored in the memory of the analyzer instead. However, Stevens (1960) sees such a strategy as simulating a basic feature of human recognition:

> "In the synthesis process, a representation of the signal at the articulatory level will certainly occur," he writes, "A similar representation may likewise exist at some stage during the reverse process of speech recognition." (p. 53)

Second Language Learning

The question whether recognition procedures should be active or passive is equally a matter of design in a second area of application, foreign language instruction, where it takes the form: should production of foreign language sounds be taught before their discrimination. Of course, the question may be resolved on other grounds, but the view that listening to a foreign language entails speaking seems just the reverse of Nelson Brooks' dictum (1959), which characterizes the modern audiolingual method, that the learner should speak only on the basis of what he has heard. Nevertheless, Hockett seems to call for just such a reversal when he states in support of a motor theory of perception, that: "...in learning a foreign language, one has considerable difficulty hearing correctly until one can also pronounce correctly."[8]

First Language Learning

Finally, the view that listening entails speaking, and the complementary view that speaking entails listening, make repeated reference to a third area of inquiry, child language. Kozhevnikov and Chistovich write as follows in their 1966 book on speech articulation and perception:

> "On considering the formation of phonemic classification system in the process of speech development in a child, the motor theory stresses

> the role of the effects of imitation of the perceived sounds. In the process of imitation are provided conditions that are favorable to the forming of the conditioned-reflex correlations between groups of sound signals and complexes of articulatory motion.... It is assumed that these conditioned reflex correlations play an important part also in the process of speech recognition by an adult."[9]

Liberman and colleagues seem to hold a related view:

> "We believe that in the course of his long experience with language, a speaker (and listener) learns to connect speech sounds with their appropriate articulations. In time, these articulatory movements and their sensory feedback (or, more likely, the corresponding neurological processes) become part of the perceiving process, mediating between the acoustic stimulus and its ultimate perception."[10]

These views of speech development are not novel. Compare the immediately preceding quotations from this decade with the theory of de Cordemoy and that of Allport (1924);

> "...the baby utters the syllable da... He receives certain kinaesthetic...and auditory sensations... Returning to the brain centers these afferent impulses are, or tend to be, redischarged through the same motor pathways as those used in speaking the syllable itself... If the ear-vocal reflexes have been sufficiently established for the sound of a word to call forth the response of articulating it, it is no longer necessary that the child himself, should speak the stimulating word. It may be spoken by another."[11]

Three centuries do not seem to have changed the position very much, except for the premise that the connections are learned[12]--and this has been challenged in part by Lieberman (1967a).

Why Conflate

Apparently, the similarity between the antecedents of listening and the consequences of speaking have led theorists to believe in their intimate and even natural relationship. Indeed, their isomorphism together with their temporal and spatial overlap, are probably two of the main reasons for the current tendency to talk about listening in terms of speaking and vice versa. Two more reasons for this conflation should be mentioned before the countervailing view is set forth here. First, there is a close correlation between patterns of articulation and the acoustic patterns that they generate (Fant, 1960). Therefore, the stimulus for speech perception can be described in either coordinate system. As it happened, articulatory phonetics began before acoustic phonetics, and the acoustic stimulus for perception is often described in articulatory terms. Perhaps the practice of talking about the stimuli as if they were articulatory encouraged scientists to think of them as articulatory after all.

A fourth factor which may be responsible for the predominance of models that conflate speaking and listening has been formulated by Galunov and Chistovich (1966) who find that a motor theory "permits the problems of speech recognition and control to be combined and thus enables a broader class of mathematical models and methods to be utilized in theoretical work." (p. 362) Liberman, Cooper, Studdert-Kennedy, Harris, and Shankweiler (1965) give a similar reason when they state:

> "It seems most unparsimonious to assume that the speaker-listener has two separate centers of equal status, one for encoding language and the other for decoding it. We would rather assume that there is only one center, with some kind of link between sensory and motor components." (p. 10)

Against Conflation

An examination of some arguments and findings that oppose the conflation of speaking and listening may begin with the "theoretical" considerations just cited: the correlation in time and form between listening and speaking, the tendency to describe the one in terms of the other, and the greater parsimony of one language center instead of two.

As for the correlations between articulation, speech wave and perception, these do not necessarily lead to the integration of speaking and listening. As Fant (1967b) suggests, the consequence may be solely that: "auditory patterns would be structured rather similar to the patterns of motor commands" (p. 2) in two rather distinct systems. In fact, according to Penfield and Roberts (1959), there are two separate language centers on the word level for motor and sensory functions, not one. As for the remaining source of conflation, it need hardly be pointed out that to describe speech by reference to articulation is one thing, to perceive it by reference to articulation another. As Fant (1963) puts it:

> "The reference to articulation primarily serves a function within the metalanguage whereby we as outside observers may conveniently describe speech. But is it actually a part of speech perception? ...The alternative view I would like to propose here is that if the auditory analysis in the hearing process has proceeded so far as to allow the proposed articulatory matching, the decoding could proceed without an articulatory reference." (p. 1)

First Language Learning

Related evidence for a separatist view comes from clinical and developmental studies. Lenneberg (1962), Fuller (1966), and MacNeilage, Rootes, and Chase (1967) have all conducted case studies of patients with congenital impairments of speech production; the diagnoses included anarthria, aphasia, and cerebral palsy. Their conclusions were, respectively:

> "An organic defect prevented the acquisition of the motor skills necessary for speaking a language, but evidence was presented for the acquisition of grammatical skills as required for a complete understanding of language." (p. 424)

> "Neither babbling, imitation, or articulate speech is necessary for understanding the natural language." (p. 5)

> "Despite the severe speech production deficits, speech perception approached normality, even in some characteristics which, according to the motor theory of speech perception, are dependent on the listener's referring to the neural correlates of normal speech motor control. Reference to normal motor information does not therefore appear necessary for these types of perceptual performance." (p. 449)

Lebrun (1968) discusses several other case reports of normal speech perception despite concurrent dysarthria, among them the reports of Fang and Palmer (1956) and Lhermitte, Gautier, Marteau, and Chain (1963). His own case study of a patient with "cortical anarthria without any concomitant dysphasic impairment" (1967) supplements the other studies in indicating that reference to articulatory movement is not required either at peripheral or at central levels, for normal speech perception.

These various findings accord with Fant's view (1967b) that "the capacity of perceiving distinctive auditory patterns on the subphonemic level [develops] in the early learning process prior to and not critically dependent of corresponding motor patterns." (p. 2) Similarly, Jakobson, in his book on child language (English translation 1968), makes reference to sounds discriminated by the child but not produced differently on the one hand, and to sounds that the child fails to discriminate which nevertheless appear as discretely different in his babbling repertoire on the other hand (p. 11 and fn 14). Also, the aphasic may produce relevant sounds but fail to discriminate them (p. 20).

Second Language Learning

Jakobson and Halle (1956) clearly favor a redress of the balance away from conflationist theories of speaking and listening when they write:

"The theoretically unlikely surmise of a closer relationship between perception and articulation than between perception and its immediate stimulus finds no corroboration in experience: the kinesthetic feedback of the listener plays a very subordinate and incidental role." (p. 34)

Their claim is clearly opposed to that of Twaddell, Liberman, and Hockett, cited at the outset, and they continue by disputing Hockett's example from foreign language learning. "Not seldom," they write, "do we acquire the ability to discern foreign phonemes by ear without having mastered their production and in a child's learning of language an auditory discrimination of adults' phonemes often precedes the use of these phonemes in his own speech." (p. 34)

Sapon (1965a) also argues that "receptive and productive language are functionally different, differ in antecedent learning conditions and make uniquely different demands on the organism":

"The analysis of a language from the point of view of its production yields a much more complex system that an analysis based on its perception, yet the teaching of both production and perception is usually based on the analysis appropriate only to the latter...what is wanted is...a micro-analysis of the behavior of the speaker as distinguished from that of the listener."[13]

Automatic Speech Recognition

If the problems of foreign language learning hardly provide univocal support for the conflation of speaking and listening, neither do those of automatic speech recognition. There are, of course, numerous strategies for recognition, some of which do not engage the issue, while yet others simulate more closely the dualist position, following so-called "passive" strategies for analysis and identification.[14] In an article entitled "Passive vs active recognition models or is your homunculus really necessary," Morton and Broadbent (1967) express two "objections to active models of speech perception in general... these are firstly that the evidence quoted in their favor is not really inconsistent with a passive explanation, and secondly that an alternative passive model is of greater generality." (p. 2)

Speech Communication (Segmental Level)

This first objection is also the thrust of a series of studies carried out by Lane and collaborators during recent years. The inference that speaking mediates listening has been argued experimentally, at the segmental level, from evidence for "categorical perception"--that is, from certain properties of identification and discrimination functions for synthetic speech continua.

However, Lane and others have obtained identification and discrimination functions with these properties along nonspeech continua both visual and acoustic.[15] Thus, Cross, Lane and Sheppard (1965) reason:

> "The postulation of a special perceptual mechanism for speech perception is not warranted.... The relations among identification probability, latency, topography and discrimination accuracy on which the motor theory is based are not at all peculiar to speech perception but are, more broadly, the result of a rather general paradigm for discrimination training and testing." (p. 74)

The motor theory of speech perception cannot adduce much support from the finding of categorical perception of speech sounds when it is shown that noises and visual patterns can be perceived categorically, too. Perhaps the most striking example of the generality of categorical perception, and hence of its irrelevance for conflating speaking and listening, comes from some studies of color perception that Lane and Kopp have been conducting.[16] In order to illustrate how closely the findings for color match those for speech, and how, therefore, they constrain the interpretation of the speech results, we may juxtapose the findings for color perception, shown in Figure 1, with a description of the findings for speech perception, taken from an article on "a motor theory of

Insert Figure 1 about here

speech perception."[17] Substituting color terms for speech terms, the article then says in paraphrase:

> "Although the [colors] lie on a [visual] continuum, the perception is essentially discontinuous. Because of the discrimination peaks at the [color-class] boundaries, the incoming [colors] are [seen] categorically...and they are therefore, quickly and accurately sorted into the appropriate [color-class]..." (p. 3)

As a description of findings, the paragraph applies as well to color as it did to speech. Discrimination (dotted line) is indeed better across color boundaries than within color classes. The sorting of colors is indeed accurate, that is, unequivocal, since the step-like labelling curves tell us that the observer always or never assigns wavelength L to color C. And the colors are sorted quickly (broken line) as well as accurately--especially the characteristic hues at the centers of the color categories.

If the article's <u>description</u> of categorical perception applies to color and to speech sounds, the same may not be said concerning its interpretation of categorical perception. Continuing the paraphrase:

> "What kind of mechanism underlies the categorical perception of the [colors]. The answer seems to us...that the perception of [color] is tightly linked to the feedback from the speaker's own articulatory movements.... In time, these movements...come to mediate between the [color] and its ultimate perception." (p. 4)

Clearly, we cannot account for diverse examples of categorical perception with a motor theory in the narrowest sense. However, a related and much more general mechanism was put forth independently by Chistovich, Klaas, and Alekin (1961), by Cross, Lane and Sheppard (1965) and, for different reasons, by Glanzer and Clark (1963). To quote the former authors:

> "The logical outline of discriminating sequences of sounds is as follows: the sound signals are transformed into the corresponding decisions...these decisions are remembered and are subsequently used in choosing a final outward reaction."[18]

Speech Communication (Suprasegmental Level)

When a speaker judges the suprasegmental characteristics of his own speech, the possible sources of cues include airborne sound (air sidetone), head sidetone, and proprioception. Of course, when the speaker stops talking and listens to someone else instead, he is deprived of most of these cues, and as a listener, he must base his suprasegmental judgments differently.

Since the sensory characteristics of speaking and listening are thus seen to be quite different structurally,[19] it is not surprising to learn that they are quite different functionally. This is the conclusion of Lane and collaborators in a series of studies over the past seven years: autophonic scales (scales of the speaker's perception of his own voice) and reception scales are systematically different (Lane, 1962). Consider loudness and stress, for example. The autophonic scale has an exponent roughly double that of the reception scale (Lane, Catania & Stevens, 1961). The disparity was established in dozens of replications of the magnitude scaling techniques and confirmed by the method of cross-modality validation (Stevens, 1959). Nevertheless, Ladefoged (1959) suggests that we judge loudness in terms of vocal level, and Warren (1962) suggests that we judge vocal level in terms of loudness. However, the reception scale is not the autophonic scale and the autophonic scale is not the reception scale. In fact, when speakers vary autophonic level in order to match changes in the loudness of a criterion stimulus, or in order to compensate for changes in sidetone loudness, or in order to maintain intelligibility despite increasing noise, in all these tasks, about the same relation is found between the dynamics of listening and speaking, and it is never the identity relation postulated by Ladefoged, Warren, and others.

Matching a criterion. Since loudness grows about half as fast as autophonic level, a listener presented with a fourfold increase in sound intensity will match it with a twofold increase in vocal level. In other words, the two-to-one ratio between the slopes (exponents) of the autophonic and reception scales yields an equal-sensation function that is linear in decibel coordinates, with a slope of about one half. Accordingly, Lane, Catania and Stevens (1961) obtained slopes of .51 and .52 in two different studies using noise intensities as the criterion stimuli. They also turned up some unpublished studies of Black (1955) which, despite considerable procedural differences, gave fair agreement (slopes about .64).[20] Lane (1962) obtained flatter matching functions (slopes .33 and .35) when he had subjects imitate two-syllable words with iambic or trochaic stress. Finally, Irwin and Mills (1965) observed that the disparity between autophonic and reception scales can be validated not only by measuring pairs of stimuli corresponding to equal sensations, as in the preceding studies, but also by measuring pairs of sensations corresponding to equal stimuli. When they had speakers produce various autophonic levels and listeners estimate their loudness, they found that the magnitudes given to the speakers and those reported by the listeners were related to each other as predicted (slopes .52 and .53 in two studies).

Compensating for sidetone. Since loudness grows about half as fast as autophonic level, a speaker presented with a fourfold increase in sidetone will restore his original loudness by halving his vocal level. In other words, the compensation function is the reciprocal of the matching function; both have exponents whose absolute value is about one half. This is just what Lane, Catania, and Stevens (1961) found when they manipulated the sidetone fed back to the speaker's ears in an interphone system, and instructed each speaker to compensate for changes in sidetone so as to hold the loudness of his voice constant, as he perceived it (obtained slope, -.46). However, subjects will compensate in this way without instruction or reflection; the same authors found that subjects asked to vocalize at a medium level produce a sound pressure that varies inversely with the sidetone gain (slope, -.42). Similarly, the unpublished measurements of Licklider and Kryter (1944) at 35,000 and 5,000 ft., and those of Lightfoot and Morrill (1949) on the ground, show that the changes in vocal level caused by inverse changes in interphone gain are governed by the disparity between the dynamics of speaking and listening (slopes -.45, -.43, and -.40, respectively). Gardner's findings (1966) are consistent with those preceding, although they embrace a wider range of slopes. Black (1951) reduced effective sidetone below normal by producing temporary threshold shifts through prolonged exposure to noise, then measured average vocal level (slope -.47). McKown and Emling (1933) found that increases in telephone sidetone at the transmitter produced decreases approximately half as great (in decibel units) in the "effective volume" at the receiver. For example, when the speaker's sidetone was increased 10 db, his listeners asked him to repeat what was said about as often as when the volume in their receivers was decreased 5 db. It is not surprising that a 10 db increase in the speaker's sidetone had the same effect as a 5 db decrease in the listener's volume, since a 10 db increase in sidetone in fact produces about a 5 db decrease in volume--according to the ratio of the autophonic and reception scales. Not unexpectedly, the compensation function tends to be flatter when sidetone is changed for only one ear and is left unchanged for the other ear: slopes between -.3 and -.4 are reported under these conditions by Lane, Catania and Stevens (1961), Fletcher, Raff and Parmley (1918), and Noll (1964a, 1964b).

Compensating for noise. Since loudness grows about half as fast as autophonic level, a speaker confronted with a fourfold increase in ambient noise will restore the perceived signal-to-noise ratio by a twofold increase in his vocal level. This is what Webster and Klumpp found in 1962 (slope .5) when they instructed their speakers to maintain intelligibility despite increasing noise. As in the case of compensation for sidetone, a smaller but comparable adjustment seems to be made automatically. Indeed, these compensatory adjustments are sometimes called the Lombard Reflex (Sullivan, 1963), after the French doctor who used the phenomenon to detect malingering early in this century (Lombard, 1911). Noise compensation functions with slopes between .3 and .4, over low to moderate noise levels, have been reported by Kryter (1946), Hanley and Steer (1949), Korn (1954), Pickett (1958), Dreher and O'Neill (1958), and Gardner (1964, 1966).[21] It may be that both kinds of compensation, sidetone penalty and the Lombard Reflex, reflect an unconscious effort by the speaker to keep the signal-to-noise ratio, and hence his intelligibility, nearly constant. When the speaker has the impression that he has succeeded in this effort, the listener has the impression that he has not--because of the differences between speaking and listening.

The sensory dynamics of listening and speaking are not only different, as shown above, but also, it seems from experiments in which their normal correlations are disturbed, they are not much related causally. When autophonic level is varied from whispering at the one extreme to shouting at the other, for example, the quality of the voice inevitably varies but the listener's judgments of loudness are practically unaffected by these variations (Lane, 1962). On the other side of the coin, one-hundred fold amplification or attenuation of sidetone level, or total masking of sidetone, leaves the autophonic scale essentially unchanged. Moreover, the speaker readily maintains a constant vocal level, when instructed to do so, despite changes in sidetone level as great as 80 db (Lane, Catania & Stevens, 1961). Furthermore, Lane has shown that congenitally deaf speakers perceive their own vocal level just as normal speakers do; they give the same autophonic scale (Lane, 1963).

Fairbanks (1954) described the "speaking system" as a servosystem,[22] emphasizing the control function of auditory feedback: "When I say a word and you repeat it, your hearing apparatus measures my word for purposes of estimation and then your word (the same word) for purposes of control" (p. 135) but the preceding evidence favors a verdict of independent over one of interdependence. To add to that evidence, here are the conclusions of Kozhevnikov and Chistovich (1966) about the control of syllable initiation:

> "Thus, it is necessary to exclude the hypothesis that acoustic changes connected with the beginning of a syllable are used by the nervous system as necessary signals for producing the command for the beginning of the next syllable...proprioceptic impulsation also is not the necessary signal...each following syllable command is given automatically; to produce the command it is not necessary to use the afferent impulsation which occurs upon the accomplishment of the preceding signal." (pp. 101ff)

Further evidence that speaking does not depend on listening in a "closed loop" fashion comes from recent research on delayed auditory feedback (DAF)[23] by Chase, Cullen, Niedermeyer, and Blumer (1967). Even though the disruptive effects of DAF are sometimes cited in support of a conflationist view of speaking and listening, the disruption of speech by exaggerated values of auditory feedback does not demonstrate that speech depends on this feedback. These investigators found that the effects of DAF are cut off during psychomotor seizure but normal speech may continue. They conclude that "speech can be elaborated without closed-loop auditory-feedback control."

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Footnotes

[1]According to Lindgren (1956).

[2]Liberman (1957; p. 122). This hypothesis is based experimentally in part on the properties of identification and discrimination functions for synthetic speech continua obtained in the following studies; Liberman, Harris, Hoffman, & Griffith (1957); Liberman, Harris, Kinney, & Lane (1961); Liberman, Harris, Eimas, Lisker, & Bastian (1961); Fry, Abramson, Eimas, & Liberman (1962); Eimas (1963).

Further discussion of these findings, advocating a motor theory of speech perception, will be found in: Liberman (1957); Lisker, Cooper, & Liberman (1962); Studdert-Kennedy, & Liberman (1963); Liberman, Cooper, Harris, & MacNeilage (1963); Liberman, Cooper, Harris, MacNeilage, & Studdert-Kennedy (1967); Liberman, Studdert-Kennedy, Harris, & Cooper (1965); Liberman, Cooper, Studdert-Kennedy, Harris, & Shankweiler (1965); Cooper (1965); Liberman, Cooper, Studdert-Kennedy, Harris, & Shankweiler (1968).

[3]Delattre (1958; p. 228). According to this line of reasoning for the motor theory, invariances in the perception of speech are more closely matched by articulatory than by acoustic invariances. Thus, the theory has a second experimental basis in certain studies of the perception of synthetic speech segments in which small differences in articulation cause large differences at the acoustic level, or conversely, viz.: Liberman, Delattre, & Cooper (1952); Liberman, Delattre, Cooper, & Gerstman (1954); Delattre, Liberman, & Cooper (1955).

Other statements of this line of argument will be found in: Liberman (1957); Cooper, Liberman, Harris, & Grubb (1958); Lisker, Cooper, & Liberman (1962); Liberman, Cooper, Harris, MacNeilage, & Studdert-Kennedy (1967); Liberman, Cooper, Studdert-Kennedy, Harris, & Shankweiler (1965); but see the alternate interpretation offered by Fant (1967a). A motor-invariance theory of vowel perception will be found in Joos (1948). The only comprehensive review of the experimental bases of the motor theory is: Lane (1965a).

In a recent review of the invariance question, Delattre seems to have changed his 1958 position somewhat: "It would seem that the acoustic correlate is closer to linguistic perception than is the articulatory correlate." (1967; p.23)

[4]Ladefoged, Draper, & Whitteridge (1958; p. 9). Also see Draper, Ladefoged, & Whitteridge (1959).

[5]Cited in Fónagy (1966; p. 238). And in Fónagy (1958): "A return to the original physiological conception of accent classically formulated by Otto Jespersen is unavoidable since accent is simply not to be defined on an acoustic level." (p. 55) Also see Gandhi, Peterson, & Yu (1960): "There is considerable reason to believe that the human observer interprets meaningful sounds in terms of the various properties of the source rather than according to the acoustical dimensions and magnitudes of the sounds." (p. 141)

[6]Lieberman (1967a; p. 162). Also see: Lieberman (1967b; 1968).

[7]Halle & Stevens (1959; 1962); Stevens & Halle (1967).

[8]Hockett (1955; p. 7). For a discussion of the relations between production and perception in foreign language learning, see Lane (1964); for studies of their sequencing, see Mace & Keislar (1965); Mace (1966) and Butt (1966).

[9]Kozhevnikov & Chistovich (1966; p. 203-204). Also see Prins (1963); Chistovich (1961); Liberman, Harris, Eimas, Lisker, & Bastian (1961); Sherman & Geith (1967).

[10]Liberman, Harris, Eimas, Lisker, & Bastian (1961; p. 177). Similarly, Rutherford (1967) writes: "The infant's auditory impressions of the sounds [he makes randomly] become linked with the coincidental patterns of tactile and proprioceptive sensation arising from the tongue, lips, and other articulators. By 8-10 months, he has heard and felt himself say 'muhmuhmuh' several thousand times and the syllables 'mama' spoken by Mother are a stimulus sufficient to evoke the nearly equivalent gesture from his own speech mechanism." (p. 249)

[11]Allport (1924; p. 182-183). A year before, Smith & Guthrie wrote: "The dependence of imitation in learning is well illustrated by language acquisition... the sounds [that the baby] makes accompany the movements that produce them and, because the vowels are sustained and the consonants either sustained or repeated, these sounds also precede the movements that continue or reiterate them. They thus become the conditioning stimuli for their own production, so that when uttered by others, they are imitated by the baby." (pp. 132 ff.)

Husson and colleagues claim that there is a demonstrable "cochleo-laryngeal" reflex, mediated by the medulla oblongata (Vannier, Saumont, Labarraque, & Husson, 1954), but several investigators have failed to substantiate the claim;

one of these (Arslan, 1964) speculates that the electrical discharges in the recurrent nerve observed after intense sound are the consequence of general reticular activation, since the discharges are also triggered by painful stimulation and are accompanied by electrical activity in various somatic muscles.

[12]For a more sophisticated hypothesis concerning the basic units in the child's auditory-vocal learning, see Skinner's concept (1957) of the "minimal echoic repertoire."

[13]Sapon (1965b; p. 136). In what we may consider a second-language experiment, Denes (1967) found no difference in learning to recognize quasi-novel speech sounds between those subjects who were and those subjects who were not able to associate the sounds with patterns of articulation. Pollack & Johnson (1959) had a similar unconfirmed expectation of the motor theory; they found that associating distinctive motor responses with elements of an auditory display did not enhance reproduction and identification of the elements.

[14]For example, Hemdal & Hughes (1967).

[15]Lane (1965a, 1965b, 1966, 1968a, 1968b); Cross, Lane, & Sheppard (1965). Also, using an acoustic-phonetic continuum that was effectively nonspeech for an aphasic patient (who was also dysarthric), Lane & Moore (1962) established identification and discrimination functions after 15 minutes of reconditioning. See also the reply to Cross, Lane, & Sheppard by Liberman, Studdert-Kennedy, Harris, & Cooper (1965). For a description of the conditioning paradigm that yields categorical perception, see Lane (1968b), and Cross & Lane (1962).

[16]Kopp & Lane (1967); Kopp (1967); Wilson & Lane (1967); Lane (1968c).

[17]Liberman, Cooper, Harris, & MacNeilage (1963).

[18]The form of the discrimination functions and the correspondence between obtained discrimination and that predicted from the identification functions can be accounted for by this hypothesis, without restriction to a specific sensory domain, on the assumption that the "decisions" involved are described by the identification functions. The degree of correspondence then depends in part on whether experimental parameters, such as the inter-stimulus interval, facilitate "deciding, remembering, and choosing."

[19]Ringel, Saxman, & Brooks (1967); Ringel & Fletcher (1967); Ringel & Ewanowski (1965); Kirikae, Sato, Oshima, & Hirose (1961); Von Békésy (1962, 1949).

[20]Melnick's procedures and findings are at variance with those reported here (1965); he suggests that suitable corrections for the marked differences in method would bring the results into alignment.

[21]Black (1950), Atkinson (1952), and Alpert (1965) obtained flatter functions, in the former cases probably because the masking signals were pure tones.

[22]Also see Fletcher (1953), Fry (1954); Peterson (1955).

[23]Chase, Sutton, & First (1959); Yates (1963).

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Figure Caption

Fig. 1. Distributions of discrimination accuracy (Correct ABX) and identification probability and latency for the hue continuum (from Lane, 1966).

OE-BR

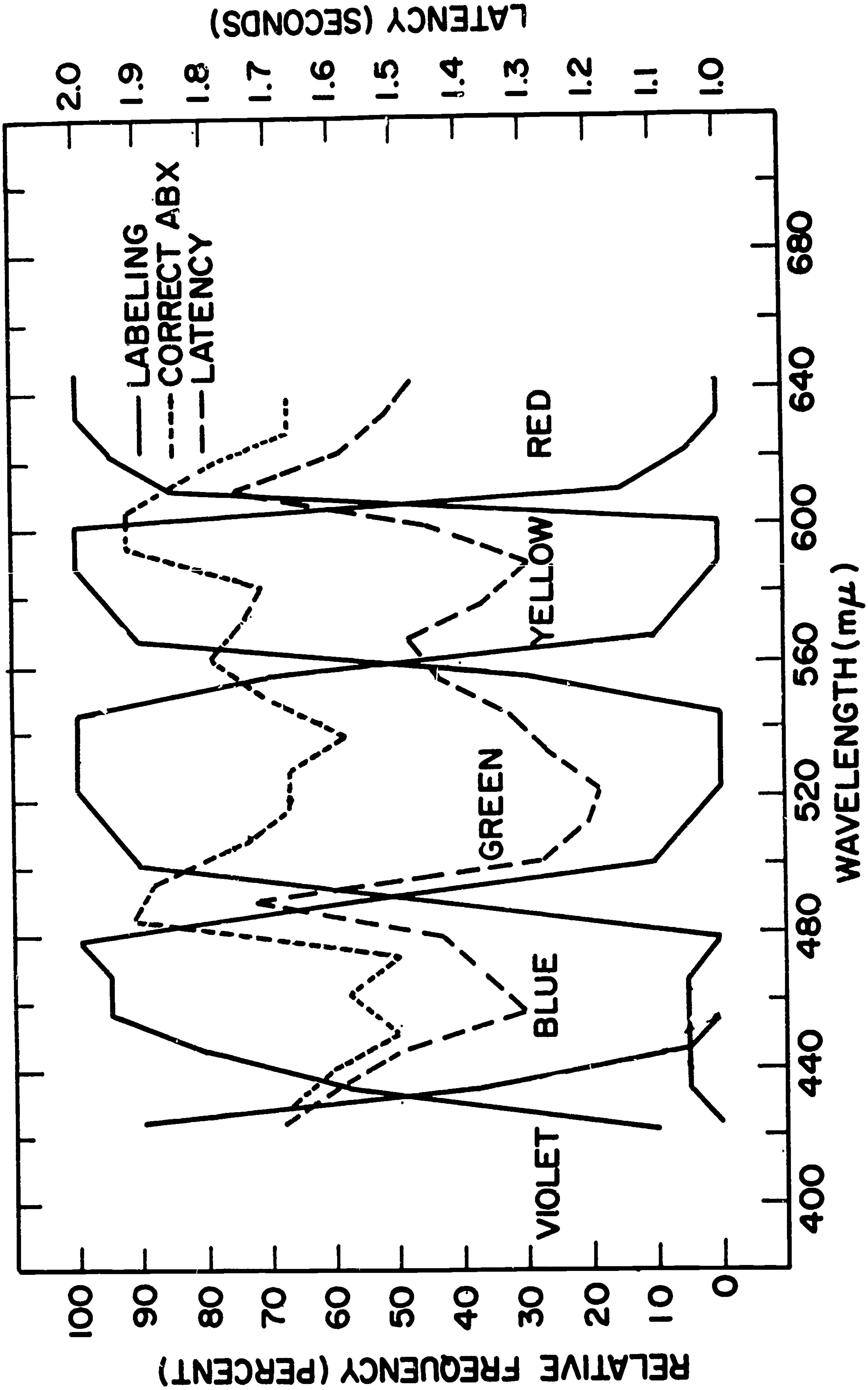

Figure 1