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EFFECT OF A PRECEDING ANCHOR UPON THE CATEGORICAL JUDGMENT OF SPEECH AND NON-SPEECH STIMULI*

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ABSTRACT

The anchoring effect in auditory perception was investigated. Three experiments were carried out in order to examine the effects of the relative positions between anchor and stimulus set on the stimulus continuum as well as on the time axis. Furthermore, the influence of stimulus attributes and complexities was investigated using pure tones, single resonance tones with formant structure, and synthetic vowels. The results indicated that the shift of the category boundary caused by the anchor shows a continuous transition from assimilation to contrast in almost all the experiments, and that contrast becomes more intense with increased stimulus complexity. A model is presented to account for these results, taking into consideration two kinds of short-term memory.

INTRODUCTION

The so-called "context effect" refers to the effects of the range and the distribution of a group of stimuli, constituting the stimulus context, upon the perception of a specific stimulus, and more generally, it refers to the effect of the background or the anchoring stimulus employed for the purpose of manipulation of scale values (Guilford, 1954). The characteris tics of context effect have been interpreted in terms of "frame of reference" (Vernon, 1952), or in terms of "Bezugssystem" by Metzger (1954). Helson (1947) developed a quantitative theory of context effect in order to predict the shift in judgments by introducing the theory of the adaptation-level (AL).

The influence of a new stimulus, which is added to a stimulus series as an anchor, upon the perception of the series stimuli has been a subject of a number of experimental studies. In a study of the judgment of lifted weights, Sherif, Taub, and Hovland (1958) reported that the introduction of a preceding anchor equal in weight to the heaviest member of the stimulus series would produce "assimilation" (i. e., overestimation of weight for the series stimuli), while an anchor outside the range of the stimulus series would produce "contrast" (i. e., underestimation of weight). Employing the basic procedure of the Sherif et al. study, however, Bravo and Mayzner (1961) found contrast but not assimilation. Assimilation was not observed as often as contrast in later studies.

Likewise, the results of studies on the anchoring effects in auditory perception have not been conclusive. Bevan, Pritchard, and Reed (1962) showed the relation of presentation-interval to the effectiveness of anchors in single-stimulus judgments of loudness. This suggests that it is not possible to define context effect only by the value of the anchoring stimulus. In vowel perception, Kanamori and Kido (1976) reported that the shift of the phoneme boundary is influenced by the difference in the context, using

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V_1CV_2 and V_1V_2 syllables. More recently, Simon and Studdert-Kennedy (1978) compared the effects of anchoring and selective adaptation on phonetic and nonphonetic judgments. It is thus necessary to specify the effect of the factors which have great influences upon the anchoring effects in auditory perception.

What we have said so far refers mainly to the shift in the categorical judgment of the target stimuli caused by a preceding anchor. The same type of shift can be observed not only in categorical judgments but also in comparative judgments. This has been called time error (Köhler, 1923). When two stimuli, which are equal in stimulus value, are presented in temporal succession as a standard and a target, there exists a constant error in comparative judgments of the two stimuli in relation to the lapse of time between the first stimulus and the second. It has been shown that if the target stimulus is presented second, the judgments show systematic tendencies toward either overestimation or underestimation. It has also been found that the duration and magnitude of this time error vary with the length of the interval between the standard and the target, and with the attribute of the stimuli (Postman, 1946). The results obtained in time error studies in which the length of the interval was varied suggest that inter-stimulus interval (ISI) has a great effect upon the categorical judgment of a target stimulus preceded by an anchor. Accordingly, it is necessary to examine the effect of ISI upon the target stimuli in an anchoring experiment. Though the effect of ISI in an anchoring loudness experiment has been studied (Yoshikawa, 1968), there appear to be no studies on the effect of ISI in pitch judgments.

The purpose of the present study is to investigate (1) the effect of spatial relationship on the stimulus continuum between anchor and target, (2) the effect of the temporal relationship between anchor and target, and (3) the effect of stimulus attributes upon the categorical judgment of a target stimulus preceded by an anchor.

METHOD

Stimuli

Three kinds of attributes were employed: (1) pitch of pure tones (in Experiment 1), (2) timbre of single resonance tones (in Experiment 2), and (3) vowel quality of synthetic vowels (in Experiment 3), as shown in Table 1. All the stimuli were prepared by using a PDP9 computer (DEC); the

Table 1

Experiments and stimuli

Experiment	Stimulus	Attribute
1	Pure tone	Pitch
2	Single resonance tone	Timbre
3	Synthetic vowel	Vowel quality

synthetic vowels were generated by computer simulation of a terminal-analog speech synthesizer, while the single resonance tones were generated by using one formant characteristic of the synthesizer, which was excited by a repetitive impulse voltage source having a fundamental frequency of 140 Hz. The synthesized signals were normalized by the overall maximum amplitude. All the stimuli were read out at a sampling rate of 12 kHz with an accuracy of 10 bits, converted into the analog waveform, and recorded through a low-pass filter with a cutoff frequency of 5.0 kHz. In Experiment 2, the resonance frequency of the single resonance tones was varied as stimulus parameters, while the bandwidth was held constant at 60 Hz. In Experiment 3, first formant frequency (F_1) of the synthetic vowels was varied, while F2, F3, F4, F5, and F6 were held constant at 1250 Hz, 2750 Hz, 3500 Hz, 4500 Hz, and 5500 Hz, respectively. The bandwidths of these formants were also held constant at 60 Hz, 100 Hz, 120 Hz, 175 Hz, 280 Hz, and 500 Hz, respectively.

As shown in Fig. 1, eight stimuli were selected as the targets, two of which were the end points of the range on the stimulus continuum and the other six were so selected that they divided the stimulus range into seven

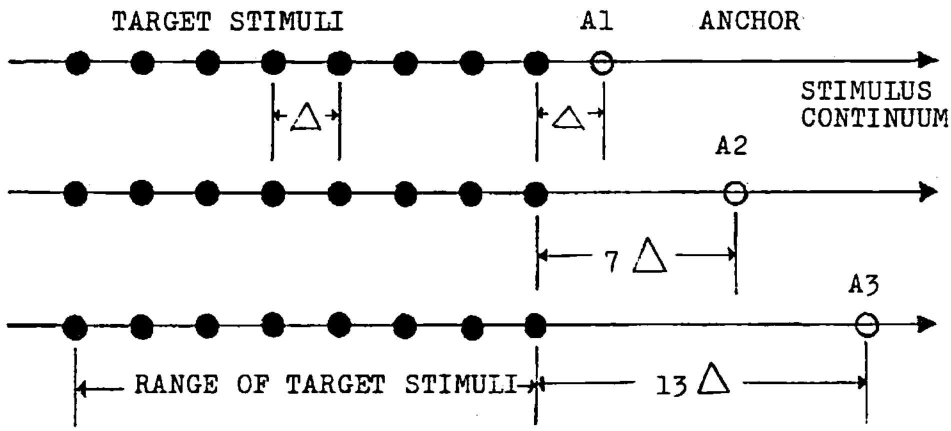


Fig.1. Placement of anchors relative to target stimuli on the stimulus continuum.

equal intervals; (1) In Experiment 1, the stimulus range was the frequency of pure tones from 528 Hz to 556 Hz, and the step size (Δ) between immediately neighboring stimuli was 4 Hz, (2) In Experiment 2, the stimulus range was the resonance frequency of single resonance tones from 560 Hz to 700 Hz; the step size was 20 Hz, and (3) In Experiment 3, first formant frequency from 440 Hz to 580 Hz, and the step size was 20 Hz. These are shown in Table 2. Other parameters of the target stimuli were kept constant in each experiment.

Preceding anchors were chosen so as to be greater than the topmost target stimulus by Δ, 7Δ, and 13Δ; they were called the A1-anchor, the A2-anchor, and the A3-anchor, respectively. They are also shown in Table 2. Positions of anchors on the stimulus continuum relative to target stimuli are shown in Fig. 1. All the stimuli were 100 msec in duration and had 10 msec rise-fall times.

Table 2

Stimulus parameters

Experiment	Variable condition			Constant conditions	
	Variable factor	Target stimulus		Anchor A1 A2 A3	Fundamental frequency
		Range	Step size(Δ)		
1	Frequency	528-556 Hz	4 Hz	560 584 608 Hz	—
2	Resonance frequency	560-700 Hz	20 Hz	720 840 960 Hz	140 Hz
3	First formant frequency	330,† 440-580, 750† Hz	20 Hz	600 720 840 Hz	140 Hz

† In session B, 330 Hz and 750 Hz were used instead of 440 Hz and 580 Hz, respectively.

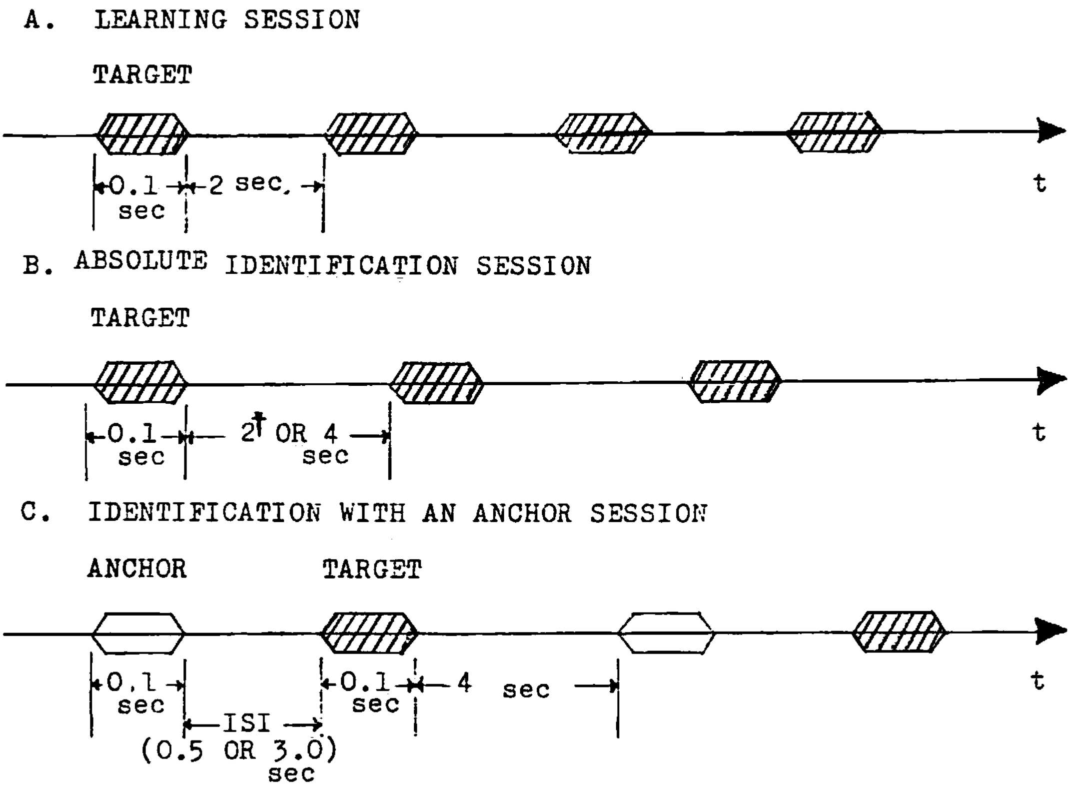
Subjects

Six young adult subjects with normal hearing were employed. Four of them participated in Experiment 1, five of them in Experiment 2, and six in Experiment 3.

Procedure

Each experiment consisted of three sessions: a learning session (called A), an absolute identification session (B), and an identification with an anchor session (C), as shown in Fig. 2. In the learning session the eight target stimuli were presented in serial order 10 times. Each subject was required to learn to identify the target stimulus as /high/ or /low/ in Experiment 1, and /bright/ or /dark/ in Experiment 2. In the absolute identification session the subjects were asked to identify the target as belonging to either one of two categories according to the category boundary acquired in session A. In the identification with an anchor session the subjects were asked to identify the target which followed the anchoring stimulus after a silent inter-stimulus interval (ISI) of either 0.5 or 3.0 sec.

Experiments 1 and 2 were carried out in the fixed order A → B → C, while the learning session was skipped in Experiment 3. The method of constant stimuli was employed in sessions B and C. In these



† In the case of speech stimuli, the intertrial interval was 2 sec.

Fig.2. Three steps in an experiment on the anchoring effect.

sessions the subject's task was to respond whether the target stimulus was /high/ or /low/ (in Experiment 1), /bright/ or /dark/ (in Experiment 2), and /a/ or /u/ (in Experiment 3). The intertrial interval was 4.0 sec. Forty judgments per each target were obtained from each subject for the 6 separate conditions in each experiment [(2 ISI's x (3 anchors)].

The recorded stimuli were presented to subjects in an anechoic room through a headphone (Rion, AP-02-MG08) at 60 dB/SPL in Experiment 1, and through a loudspeaker (JBL-4320) at 78 dB(c) in Experiments 2 and 3.

RESULTS

The probability that a stimulus will be identified as belonging to either one of two categories can be generally approximated by a cumulative normal distribution (Guilford, 1954). The responses that the target stimulus is identified as /high/ (in Experiment 1), /bright/ (in Experiment 2), and /a/ (in Experiment 3) in sessions B and C, were approximated by a cumulative normal distribution whose mean and standard deviation were calculated by

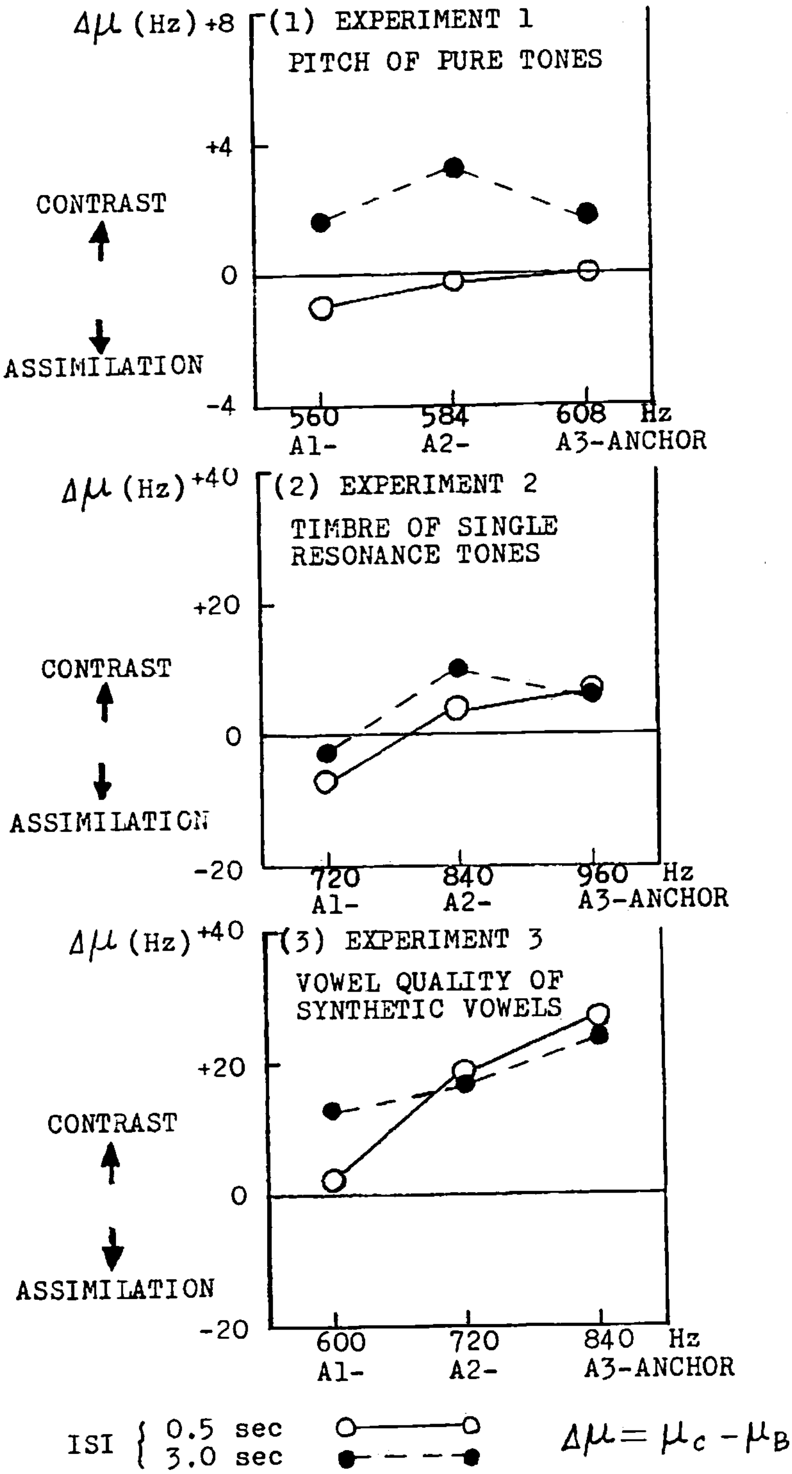


Fig. 3 Anchoring effects in terms of the shift of the category boundary.

the method of maximum likelihood solution. They were represented as (μ_B , σ_B) in session B and (μ_C , σ_C) in session C. The mean corresponds to the category boundary (or the phoneme boundary), while the standard deviation serves as an index for the accuracy of identification. The difference $\Delta\mu$ between μ_C and μ_B can be regarded as an index for the anchoring effect. A plus sign for $\Delta\mu$ indicates a shift of the category boundary toward the preceding anchor (meaning contrast), while a minus sign indicates a shift in the opposite direction (meaning assimilation).

The pooled identification performances of alll the subjects are plotted as a function of preceding anchors in Fig. 3, where solid and broken lines indicate the shift of the category boundary of the target stimuli for the two conditions of ISI: 0.5 and 3.0 sec, respectively.

Let $\Delta\mu_t$ denote the shift of the category boundary for the ISI=t sec. The effect of the ISI upon the shift on the category boundary can then be seen in the difference between $\Delta\mu_{3.0}$ and $\Delta\mu_{0.5}$, as shown in Table 3. A plus sign represents the fact that a shift of the category boundary at ISI=3.0 sec shows more contrast or less assimilation effects than at ISI=0.5 sec. A minus sign represents the fact that a shift at ISI=3.0 sec shows more assimilation or less contrast effect.

Table 3

Difference between $\Delta\mu_{3.0}$ and $\Delta\mu_{0.5}$ in Hz

Anchor / Experiment	A1	A2	A3	(Step size)
1	2.80**	3.36**	1.81**	(4 Hz)
2	4.73	5.40	-0.37	(20 Hz)
3	10.61**	-1.22	-1.98	(20 Hz)

** $p < .01$ One-tailed t-test

The contrast and assimilation effects in each attribute of the stimuli can be summarized as follows.

Pitch Judgment: As shown in Fig. 3(1), at ISI=3.0 sec, contrast was more conspicuous than at ISI=0.5 sec, with this shift of the category boundary under the A2-anchor condition showing more contrast effects than under the A1 and the A3 conditions. As shown in Table 3, in every condition of anchor there were significant differences between at ISI = 0. 5 sec and at ISI = 3. 0 sec. Assimilation was observed under the A1 condition at ISI = 0. 5 sec.

Timbre Judgment: As shown in Fig. 3(2), contrast was more conspicuous with the increases in the resonance frequency of a preceding anchor except the A3 condition at ISI=3.0 sec. There were no significant differences between at ISI =0. 5 sec and at ISI = 3. 0 sec, though the shift showed more contrast effects when the ISI was 3. 0 sec, which was similar to the result in pitch judgment. Assimilation was observed under the A1 condition.

Phoneme Judgment: As shown in Fig. 3(3), consistent with the results obtained in timbre judgment, contrast was more conspicuous with the increases in the first formant frequency of an anchor at both ISI=0.5 sec and ISI=3.0 sec. The shift of the category boundary was not significantly affected by changes in ISI, except the A1 condition. Assimilation was not observed in any condition.

DISCUSSION

From the results obtained in the present study, it can be said that anchoring effect is influenced by the spatial separation between anchor and target on the stimulus continuum as well as by their temporal separation, regardless of whether the stimulus is a speech or non-speech stimulus.

Effect of spatial separation between anchor and target

With a few exceptions, the shift of the category boundary shows more contrast as the spatial separation between anchor and target on the stimulus continuum increases. This result reflects the fact that the presentation of an anchor shifts the frame of reference toward the anchor, and thus moves the point of subjective equality (PSE) toward the anchor. Consequently, the responses for the /low/- (in Experiment 1), the /dark/— (in Experiment 2), and the /u/-category (in Experiment 3) increases. It can be said that the effect of the anchor upon the shift of the category boundary ultimately approaches zero as the spatial separation between anchor and target on the stimulus continuum becomes greater. Accordingly, the reduction of contrast under the A3 condition at ISI =3.0 sec in Experiments 1 and 2, can be considered as being due to the decrease of the anchoring effect upon the target stimuli.

Effect of temporal separation between anchor and target

The results indicate that the influence of ISI upon the anchoring effect is not constant but varies with the attribute of the tones. Under the non-speech condition, contrast was more conspicuous at ISI=3.0 sec than at ISI= 0.5 sec, while under the speech condition (with the exception of the A1 condition), the category boundary was not significantly influenced by changes in ISI. These results thus reflect that the shift of the category boundary shows greater contrast as the complexity of the stimuli increases.

Although the experimental data are certainly not sufficient to draw a general conclusion on the anchoring effect, the findings of the three experiments can be interpreted as suggesting the continuous transition from assimilation to contrast when the spatial/temporal separation between the anchor and the target is increased. The situation is schematically indicated by Fig. 4. The three curves for the pure tone, the single resonance tone, and the synthetic vowel may be essentially similar to each other, though their crossover points from assimilation to contrast are different.

The results of the present study strongly suggest that the anchoring effect is caused by two factors which exert mutually opposite influences upon the category boundary for the target stimulus. The two factors may be associated with two distinct short-term storage systems: precategorical and categorical. Following Fijisaki and Kawashima (1971a, 1971b), we present here an interpretation based on a model of the perceptual mechanisms and processes in the anchoring experiment. The following are the basic postulates for the model.

(a) Two kinds of short-term memory are supposed for the memory of a preceding anchor. One of them is a precategorical short-term memory for the position of a preceding anchor on the sensation continuum and retains an analog and continuous form of information. This short-term memory is named STM1. The information stored in STM1 is liable to lapses or to fluctuations during the course of retention and retrieval. The other is a categorical short-term memory for the category (or the phoneme) of a preceding anchor, which is identified on the basis of the category boundary (or the phoneme boundary), and it retains a discrete and encoded form of information. This short-term memory is named STM2. The information stored in STM2 remains quite stable at least for a period of several seconds.

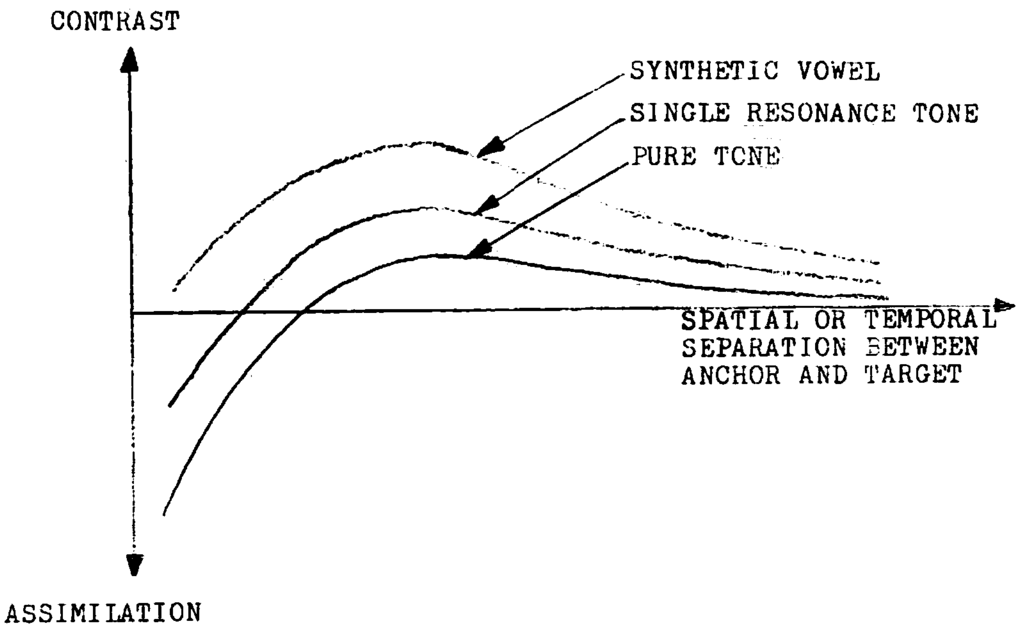


Fig. 4 Assimilation and contrast effects in the categorical judgment of speech and non-speech stimuli.

(b) Whether assimilation or contrast is caused by the anchor depends upon the direction of the shift of the category boundary. Though the category boundary is mainly determined by the information stored in long-term memory (LTM), it can be shifted by the influences of the two short-term memories. Assimilative shift is assumed to be caused mainly by the influence of STM1, while contrastive shift is assumed to be caused mainly by the influence of STM2.

(c) The influences of both short-term memories are assumed to decay monotonously with an increase in the spatial or temporal separation between anchor and target.

(d) The magnitudes of the influences of the two short-term memories vary depending on the attribute of stimuli.

Figure 5 shows the auditory perceptual processes with the two short-term memories, STM1 and STM2. The first block, AUDITORY MAPPING represents the auditory process for mapping the stimulus continuum to the sensation continuum. The output from AUDITORY MAPPING is stored in a short-term memory STM1. The output from AUDITORY MAPPING is at the same time fed to the next stage of CATEGORICAL JUDGMENT. The output from CATEGORICAL JUDGMENT is stored in a different short-term memory STM2. The category boundary for the identification of the stimulus in block CATEGORICAL JUDGMENT is determined by the influence of a long-term factor and short-term factors. The former is the information stored in the long-term memory LTM, which has been acquired during many years of language learning in the case of speech stimuli, but by a very brief period of learning in the case of non-speech stimuli. The latter are the influences of two kinds of short-term memory STM1 and STM2. The process in which the category boundary is determined by LTM, STM1, and STM2 is shown as SUM. From the assumption (b), assimilation is caused when the influence of STM1 upon the determination of the boundary is

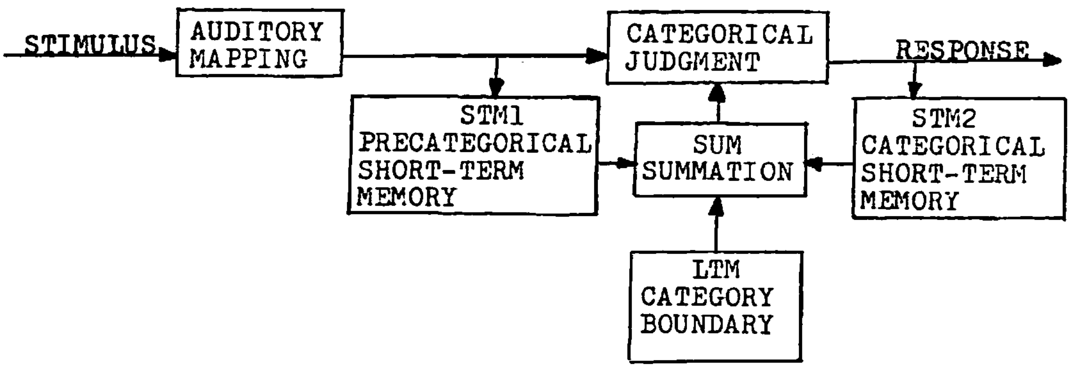


Fig. 5 A model of auditory perception with two STM's as possible causes of the anchoring effect.

greater than that of STM2, while contrast is caused when the influence of STM2 is greater than that of STM1.

In summary, the present study has elucidated not only the effect of the spatial relationship between anchor and target on the stimulus continuum upon the anchoring effect, but also the effect of their temporal relationship as well as the effect of the stimulus attribute which have not been taken up by the adaptation-level theory. A model has been presented for the perceptual mechanisms and processes involved in the anchoring experments, assuming two kinds of short-term memory for the anchor exerting oppositive influences (assimilation vs. contrast) upon the categorical judgment on the target stimulus. The model has been shown to be capable of qualitatively explaining the continuous transition from assimilation to contrast observed in the present study. Further experimental studies, however, are clearly necessary for the quantitative specification of the details of the model.

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