FEATURE ANALYSIS OF PHONETICALLY BALANCED MONOSYLLABIC WORDS RETRIEVED AT THE SUBCEPTUAL LEVEL

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ABSTRACT

Fifty phonetically-balanced monosyllabic words were presented subceptually in the absence/presence of noise to study the type of cues employed by the subjects to retrieve the words. The same words were also presented at normal threshold level to check whether similar cues operated under subthreshold and normal threshold conditions. The results indicated that at subceptual level, the subjects obtained partial cues on the basis of which they provided structurally related retrievals. Confusions between the stimulus words and retrieved words were found to occur due to sharing of certain common features like acoustic similarity, rhyme, and nasality, etc. Frequency of usage and correct retrieval were positively correlated. Further, the level of confidence placed in the retrievals was of "doubtful" or "guessing" nature. In general, word perception at subceptual level required consulting the internal lexicon and "filling in" the missing information.

Word perception at subceptual level has been largely studied by presenting the words visually outside the level of awareness with a view to establish a semantic-associative relationship between the stimulus and response (Dixon, 1956, 1958 ; Bach, 1959; Pine, 1961 ; Spence and Gordon, 1967; and Gordon, 1967). While no attempt has been made to analyse the features of words perceived subceptually, some interesting findings were obtained in some of the studies. Bricker and Chapanis (1953), Murdock (1954) and Frederiksen (1971) concluded that under difficult perceptual conditions, a lot of information is contained in an erroneous response regarding the phonetic characteristics of the word to rule out all but a restricted set of alternatives from which the subject chooses a word at random to serve as his guess.

In the present series of experiments, an attempt has been made to analyze the features that can be perceived by the subject when phonetically-balanced (PB) monosyllabic words are presented subceptually. Subception was operationally defined as the sound intensity level where the subject would give approximately 25% correct retrievals. It was assumed that the subceptually

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presented word stimuli would provide part-cues to which the subjects respond in a predictable manner. This assumption is based on the conclusion drawn from a group of experiments (Goldberg and Fiss, 1959 ; Fuhrer and Eriksen 1960 ; Wiener and Schiller, 1960 ; Guthrie and Wiener, 1966) in which a relationship was found between degree of awareness of a visual stimulus and the emitting of a structurally similar or identical response.

EXPERIMENT I

In the first experiment, PB monosyllabic words were presented at a predetermined subceptual sound intensity level so as to analyze the features perceived by the subject. It was hypothesized that 1) the subject would perceive certain features of the stimulus words on the basis of which he would provide structurally related retrievals, 2) confusions between stimulus words and retrieved words will occur due to sharing of certain common features, 3) frequency of usage and correct retrieval will be related, and 4) level (degree) of confidence placed in the retrievals will be of "doubtful" or "guessing" nature.

Method

Subjects : The subjects were 20 students, 10 males and 10 females, from Delhi University, between the age range of 18-25 years. The subjects were taken randomly. It was ascertained from them that they did not suffer from any obvious hearing defects and that they had good amount of knowledge of English.

Stimulus materials and Apparatus : The stimulus material consisted of PB monosyllabic words from Auditory test W-22, standardized by Central Institute for the Deaf (St. Louis, Missouri). PB word lists 2A and 2B consisting of 50 monosyllabic words arranged in two different orders were used for training- The four speed H.M.V. record player (Model No. AT6, Gerrard, Made in England) was used to play the records containing the word lists. Two sets of muffler type headphones with impedence of 8 ohms. were used, one for the experimenter and one for the subject to hear the words. To record the subjective level of confidence, a panel consisting of three push buttons marked '1','2', and '3' connected with three torch bulbs was designed. The marks '1', '2' and '3' referred to three levels of confidence namely 'heard clearly', 'with doubt but something heard', and 'pure guessing'.

Procedure : The design of the experiment involved, first of all, determination of the sound intensity level where the subjects would, on the average, give approximately 25% correct retrieval. Method of limits was used for this purpose. Lists 2A and 2B were played alternatively in ascending and descend-

ing order varying the sound intensity level in gradual steps. A group of 10 students other than those used in the main experiment served as subjects for this purpose. The subjects were instructed that they would hear the words one by one through the headphones. They should listen carefully and repeat the words immediatelly after.

The sound intensity level was gradually varied from highest to the lowes level where the subjects reported no awareness of the stimulus words. The sound intensity level (range 24 to 26 db as measured at the subject's headphone by the sound level meter, Model No. 1551-C, General Radio Company, Concord, Massachusetts, U.S.A.) where the subjects, on the average, gave approximately 25% correct retrieval was fixed to work as subceptual level for presentation of words for all the subjects in the main experiment.

Sufficient training was given to the subjects before starting with the main experiment, to familiarize them with the American accent as well as the overall procedure. The sound intensify level was fixed at the predetermined subceptual level. The record with lists 2A and 2B were played through with a rest pause of 10 minutes in between. Instructions emphasized the subjects to listen to the words presented through the headphones and repeat each word immediately after, They were asked to press one of the three push buttons to indicate the degree of confidence for each retrieval. Word retrievals as well as the confidence ratings assigned to each were recorded.

Results

Total number of retrievals possible for 50 words presented twice (list 2A and 2B) to 20 subjects was 2,000 (50 x 2 x 20) out of which 1796 retrievals were obtained and rest were missed out. Data was analyzed in terms of both correct and incorrect retrievals. Incorrect retrievals were classified into 1) related and 2) unrelated. Related retrievals were further classified into i) transformations of the initial phonemes of the stimulus words (initial transformations), ii) transformations of the final phonemes of the stimulus words (final transformations), and iii) other transformations including errors of omission or commission and change of mid_vowel or consonant of the stimulus words. Unrelated retrievals bore no such structural resemblance with the stimulus words as described for related retrievals.

Percentage of correct, related, and unrelated retrievals was 18.49, 44.11 and 37 25 respectively. The percentage of correct and related retrievals taken together was significantly higher than the percentage of unrelated retrievals (x^2 = 116 8, p 0.01 for df = 1). This was interpreted to indicate that the

subject perceived certain cues on the basis of which he provided retrievals bearing structural resemblance with the stimulus words. Out of related retrievals, those with initial, final, and other transformations of the phonemes of the stimulus words were 14.76%, 20.94%. and 8.41% respectively. Retrievals with initial transformations were significantly less than retrievals with final transformations ($x^2 = 18.86$, p 0.01 for df = 1).

Word retrievals for each of 50 stimulus words were examined to study the common features shared by the stimulus words and retrieved words. It was observed that most of them shared the feature of acoustic similarity. For example, for stimulus word 'ham'-word retrievals like 'had', 'hair', 'hand', 'has' 'when', 'can' etc., were regarded as acoustically similar retrievals. On the whole, 60% of the retrievals (including correct) were found to be acoustically similar retrievals.

Rhyme defined as words in which there is consonance of the terminal sounds was found to be operating in 41.5% (including correct) of the total retrievals.

A distinctive feature analysis of the misperceived initial and final phonemes of the stimulus words was also attempted to test the hypotheses whether the confusion between phonemes of stimulus words and retrieved words occurred pue to sharing of common distinctive features. For this purpose, only those stimulus words for each of which a particular word retrieval was repeatedly given (high frequency retrieval) were considered Consulting Table 1 (Clark and Clark, 1977) of distinctive features of English consonants it was found that of 29 stimulus words having high frequency retrievals, in approximately 50% of the cases, confusion errors between the initial or final phonemes of the stimulus words and retrieved words occurred due to either a common manner or place of articulation or a common voicing feature. However, in general, the subjects, upon receiving partial cues, seemed to be supplying words bearing acoustic similarity with the stimulus words

In case of stimulus words containing nasal sounds : (n, m, ng), nasality was found to be an important feature for identification. Out of the total word retrievals for 16 stimulus words containing nasal sounds, 51.4% (including correct) had nasal sounds in them.

TABLE 1

The English Consonants

Symbols on the left side of each column are voiceless, those on the right side are voiced

	Place of articulation						
Manner of Articulation	Bi-Labial	Labio-Dental	Dental	Alveo-lar	Palatal	Velar	Glottal
Stops	Pb			td		KG	
Fricatives		FV	AJ	SZ	vv SZ		h
Affricates					vv CJ		
Nasals	m			n		e	
Lateral				1			
Semivowel	w			r	Y		

Stimulus words beginning with vowels (vowel words) were often confused with other vowel words. For 12 vowel words, 61.1% of the retrieved words (including correct) were vowel words. 38.9% were consonant words of which 21.6% began with 'h'. Thus vowel words **were** generally either confused with other vowel words or words beginning with **'h'.**

Frequency of usage and correct retrieval : Frequency of usage of 50 stimulus words was determined for Indian University Students on the basis of a written and spoken account. Of the 50 stimulus words, 12 were found to be of high frequency of usage, 20 of medium, and 18 words were of low frequency of usage. A significant positive spearman rank order correlation (rho=61 p 01, df=48)was obtained between frequency of usage and correct retrieval. Thus words of high frequency of usage were identified correctly significantly more often than words of medium and low frequency of usage. A chi-square test also revealed that percentage of correct retrievals was significantly greater for words of high frequency of usage than for medium and low ($x^2 = 144.54$, p 0.01 for df=4). The trend was reversed for unrelated retrievals.

Degree of Confidence and word retrieval   Per cent distribution of overal retrievals under 'with doubt' (WD) category was the highest (45.1%), next highest (33.8%) was under 'pure guessing' (PG) category with least cumber of retreivals placed under 'heard clearly' (HC) category of confidence. The retrievals placed under three levels of confidence were observed to be significant $(x^2 = 156.08,\ p\ 0.01\ for\ df=2)$.

When the percentage of correct and related, and correct and unrelated retrievals was compared with regard to level of confidence, results revealed that significantly greater confidence was placed in correct than incorrect retrievals. x^2 values being 48.33 and 52.9 respectively. Further, the results showed that retrievals for words of high frequency of usage were given with significantly greater confidence than retrievals for words of medium and low frequency of usage $(x^2 = 12.38,\ p\ between\ .01\ and\ .02\ for\ df=4)$.

Discussion :

At subceptual level, the subject, if not being able to identify the words correctly, at least, provided word retrievals bearing structural resemblance with the stimulus words on the basis of partial cues obtained. Receiving cues from initial, final or any other part of the stimulus words, the subject "filled in" the rest of the information- This is in accordance with the partial cue hypothesis advocated by Wiener and his associates (Goldberg and Fiss, 1959; Wiener and Schiller, 1960; Guthrie and Wiener, 1966) who stated that the subject on some of the "incorrect" trials at least perceive some portion of the stimulus, perhaps not sufficient to make a correct report, but that the subject makes a response which is some portion of the total correct response he would have made if he had perceived all of the stimulus (Eriksen, 1956).

What words would be retrieved will depend not only upon redundancy but also upon the internal lexicon (Massaro, 1975). According to a recognition model provided by Rubenstein, Lewis and Rubernstein (1971), four stages are involved in word recognition: 1) Quantization, 2) marking, 3) comparison, and 4) selection. The present findings may be interpreted with the help of this model that upon receiving fragmentary information, the subjects may search the internal lexicon, make comparisons between the phonetic information obtained and marked lexicle entries, and finally select the word which is in agreement with the received information. Related and un-related word retrievals may be interpreted by an analysis-by-synthesis model (Neisser, 1967) according to which, hearing an utterance, the listener's preliminary speech analysis may pick out a few distinctive features which suggest a tentative answer

to various related words are then synthesized until one of them fits. The Listener, thus, otten manages to hear words which were not in the input at all.

Confusions between the stimulus words and retrieved words were found to occur due to sharing of Certain common features as acoustic similarity, rhyme, nasality and identification of vowel sounds. Vowels in the initial position of the stimulus words were also found to be confused with words beginning with 'h'. This may be because that many vowels accompany a glottal sound (h) when spoken in context with other consonants and vowels

A distinctive feature analysis, however, revealed that only in case of approximately 50% of the stimulus words having high frequency retrievals, confusions between the initial and final phonemes of the stimulus words and retrieved words occurred due *to* either a common manner or place of articulation or a common voicing feature, On the whole, it appeared that word retrievals were provided on the basis of the lexicle knowledge as well as auditory information rather than analyzing the individual phonemes in the word. GanongIII (1980) pointed out that in word perception lexicle knowledge and auditory information interact. A bias toward phonetic categorizations that make words operates as a correction process.

A positive correlation (rho) obtained between frequency of usage and correct retrieval may be supported by the findings of many studies (Howes and Solomon, 1951 : Howes, 1954 ; Postman and Rosenzweig, 1956 : Rubenstein, Garfield and Millikan, 1970)

As the subjects most of the times made use of 'with doubt' category of confidence, this further is an evidence that certain part cues were received by the subject. Moreover, greater confidence shown in retrievals of words of high than medium and low frequency of usage may be interpreted as that these words probably tend to be more prominent in the internal lexicon and require smaller fragments for recognition (Postman and Rosensweig, 1956).

EXPERIMENT II

Experiment II was conducted to study the effect of background noise on retrieval of words presented subceptually. The cues available to the subject were already minimised in Experiment I, it was expected that noise would further degrade the cues. Some of the important cues may not be received thus bringing down the intelligibility scores. The hypotheses tested in Experiment I were further put to test in Experiment IT where the same PB word lists embedded in white noise were presented at the same subceptual level as in Experiment I.

Method

Subjects : The subjects were a fresh group of 20 students, 10 males and 10 females, sampled from the same pool as for Experiment I.

Stimulus material and Apparatus : The word lists and apparatus were the same as used in Experiment I. The amplified output of the recorded word lists was fed to the Noise-Generator (Model 901 B, Grason-Stadler, West Concord Massachusettes, U.S.A.) which was driven to the subject's headphones through which the noise as well as the words could be heard at an overall sound intensity of 26 db.

Procedure : Subceptual sound intensity level of the stimulus words was kept the same as in Experiment I. The rest of the procedure was identical to that of Experiment I except that the subject in this case was informed that the words would be heard against a background of white noise.

Results :

Percentage of correct, related and unrelated retrievals obtained in the presence of noise was 9.9, 48.4 and 41.7 respectively. Percentage of correct and related retrievals taken together was sign ificantly higher than the percentage of unrelated retrievals ($x^2 = 48.38$, $p < 0.01$ for df=1) thus indicating that under noise condition, the subject could perceive certain features on the basis of which he provided retrievals bearing structural resemblance with the stimulus words.

Per cent retrievals with initial, final and other transformations of the phonemes of the stimulus words were 17.19, 13.79 and 17.42 respectively. Retrievals with initial transformations were significantly greater than those with final transformations ($x^2 = 6.6$, p=0.01 for df = I). In all, 55% of the retrievals shared the feature of acoustic similarity with the stimulus words. Rhyme was found to be operating in 36.9% of the total retrievals.

Distinctive feature analysis of the misperceived initial and final phonemes of the stimulus words having high frequency retrievals revealed that only in 33.3% of such words, the confusions between the initial and final phonemes of the stimulus words and retrieved words occurred due to sharing of either a common manner or place of articulation or a voicing feature. In general, the subjects relied on the overall sound-shapes rather than perceiving the individual phonemes in the words.

Of the retrievals for stimulus words containing nasal sounds. 38.9% (including correct) contained the feature of nasality. For vowel words, 46.2% of

the retrieved words were vowel words, 53.8% were consonant words of which 16.5% words began with 'h'.

Frequency of usage and correct retrieval :   Frequency of usage and correct retrieval were found to be postively correlated (rho= .53. $p<$ .01 df=48) thus indicating that words of high frequency of usage could be identified correctly significantly more often than words of medium and low frequency of usage. Further, percentage of correct retreivals was significantly greater for words of high than for medium and low frequency of usage (x^2=65.66, p<0.01 for df=4). This trend was reversed for unrelated retrievals

Degree of confidence and word retrieval : Retrievals, in general, were either placed under 'with doubt' category (45.5%), or 'pure guessing' category (44%) of confidence, with a few (11%) rated as 'heard clearly' (x^2=392.34, p<0.01 for df=2).   When the percentage of correct and related, and correct and unrelated retrievals was compared with regard to level of confidence, the x^2 values of 64.49 and 80.79 respectively were significant beyond .01 level for df=2.   The results thus showed that significantly greater confidence was placed in correct than incorrect retrievals.   Further, it was found that overall retrie- vals for words of high frequency of usage were given with significantly greater confidence than those for words of medium and low frequency of usage ($x^2 = 7.01$, p<0 01 for df=4).

Discussion :

The results revealed that even when words were subceptually presented against a background of noise, the subject could extract relevant features from the initial, final or any other part of the stimulus words on the basis of which he retrieved words bearing structural resemblance with the stimulus words. Thus on the basis of perceived part cues, rest of the information was filled in.

As the presence of background noise had made the identification task much more difficult than that was found under without noise condition (Experiment I), it seemed that the subjects were mostly relying on the overall sound shapes of the words.   The phonemic confusions could barely be explained in terms of distinctive feature analysis.   The subjects, in general, on receiving fragmentary cues seemed to be trying to search for those words in the internal lexicon which matched maximally with the phonetic information obtained.   The cues found to be operating under without noise condition were the same as found under noise condition, though they were further degraded (e.g., acoustic similarity and rhyme decreased from 60% and 41.5% respectively,

under without noise condition to 55% and 36 9% respectively, under noise condition).

Frequency of usage and correct retrieval were found to be positively correlated as in Experiment 1. As the addition of noise had made the identification task much more difficult, subjects employed more of 'guessing' than what was found in Experiment I. However, in both the experiments, greater confidence was placed in correct than incorrect retrievals. Also, significantly greater confidence was placed in retrievals of words of high frequency of usage than for medium and low frequency of usage.

EXPRIMENT III

Experiment III was designed to study the features that operate at 50% correct retrieval level (normal threshold). The major purpose underlying was to study whether similar cues are obtained under normal and subcepiual (without/with noise) conditions. It was expected that the magnitude of features perceived would definitely be more under normal threshold than under subthreshold conditions, however, the type or nature cf cues obtained would be more or less the same. It was hypothesized that percentage of correct retrievals will be significantly greater than percentage of incorrect retrievals ; that confusions between stimulas words and retrieved words will occur due to sharing of certian condition features ; that frequency of usage and correct retrieval will be related.

Method:

Subjects: A fresh group of 10 students. 5 males and 5 females, sampled from the same population as for Experiment I and II, served as subjects for the present experiment.

Stimulus material and Apparatus : The word lists and apparatus were identical to those used in Experiment I.

Procedure: From the data collected in Experiment I on determination of subceptual sound intensity level, the level where the subjects, on the average, could give approximately 50% correct retrievals (28 to 30 db) was fixed for presentation of stimulus words in the present experiment. The procedure remained the same as for Experiments I and II except that the degree of confidence was not recorded as during training, it was found that by and large, the subjects placed their retrievals in the 'heard clearly' category of confidence.

Result's :

Percentage of correct, related and unrelated retrievals was found to be 62.1, 34.1 and 3.4 respectively. Per cent correct retrievals were significantly greater than incorrect retrievals ($x^2 = 58.26$, p < 0.01 or df=1) Percentage of initial, final, and other transformations of the phonemes of the stimulus words was 12.6, 8.5 and 13.0 respectively, with initial transformations being significantly greater than final transformations ($x^2 = 7.96$, df = 1, p < 0.01.)

In all, 89.5% of the total retrievals shared the feature of acoustic similarity with the stimulus words. Rhyme was found to be operating in 36.2% of the total retrievals.

Distinctive feature analysis of the misperceived initial and final phonemes of the stimulus words revealed that in cases of 64.3% of the stimulus words having high frequency retrieval, confusion between the phonemes of the stimulus words and retrieved words occurred due to either sharing a common manner or place of articulation or a common voicing feature.

Of the retrievals for words containing nasal sounds, 95 3% (including correct) contained nasal sounds in them. For vowel words. 92.1% (including correct) of the word retrievals were vowel words, 7.9% were consonants words of which 7 5% words began with 'h'.

Frequency of usage and correct retrieval: A positive correlation (rho = .28, df=48, significant at .05) was found between frequency of usage and correct retrieval thus showing that words of high frequency of usage could be identified correctly significantly more often than words of medium and low frequency of usage. Percentage of correct retrievals was found to be significantly greater for words of high frequency of usage than for words of medium and low frequency of usage (x^2=31.4, p < 0.01 for df=4). This trend was reversed for incorrect retrievals.

Discussion ;

The results of the present experiment may be taken to lend support to the findings of the first two experiments that similar cues operate at 25% and 50% correct retrieval level Only difference was that magnitude of features perceived at 50% correct retrieval level increased due to which the percentage of correct retrievals increased significantly in comparison to the one obtained at subceptual level. Figure I depicts the percentage of correct, related and unrelated retrievals at subceptual and 50% correct level.
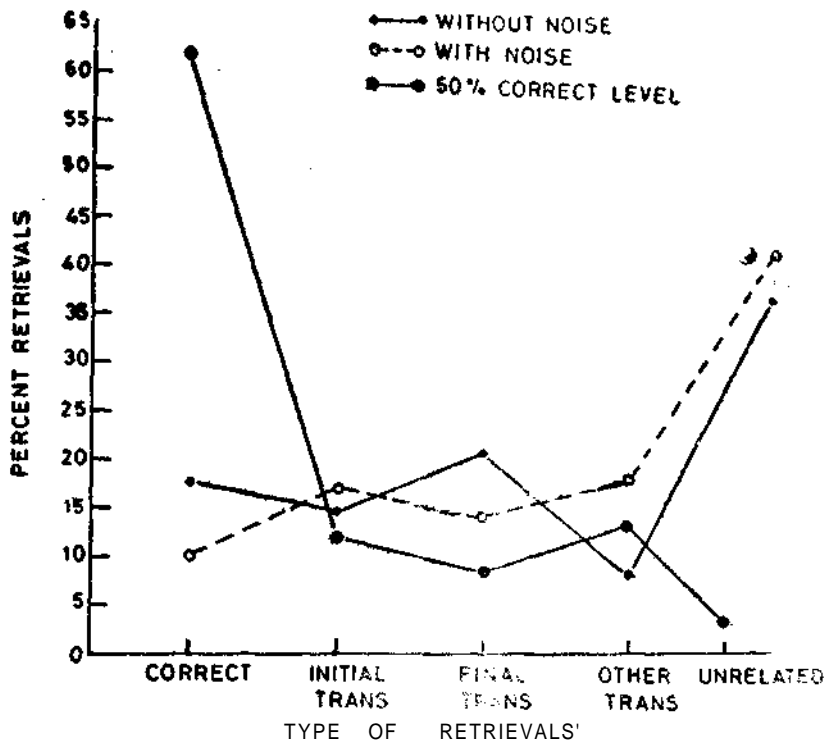
FIG: PERCENTAGE OF VARIOUS TYPES OF RETRIEVALS UNDER THREE EXPERIMENTAL CONDITIONS: SUBCEPTUAL WITHOUT NOISE (EXPERIMENT I), SUBCEPTUAL WITH NOISE (EXPERIMENT II), 50%. CORRECT LEVEL (EXPERIMENT III).

Fig-1

Analysis of related retrievals under three experimental conditions revealed that the cues were received from initial, final or any other part of the stimulus words, with features extracted more from the final than initial parts in Experiments II and III   In general, the subjects seemed to be relying on the overall sound shape of the stimulus words on the basis of which they tried to provide meaningful words matching maximally with the perceived features.

Confusions between stimulus words and retrieved words occurred due to sharing of certain common features such as acoustic similarity, rhyme, nasality etc., under all three experimental conditions   l-Fig-2 Words of high frequency
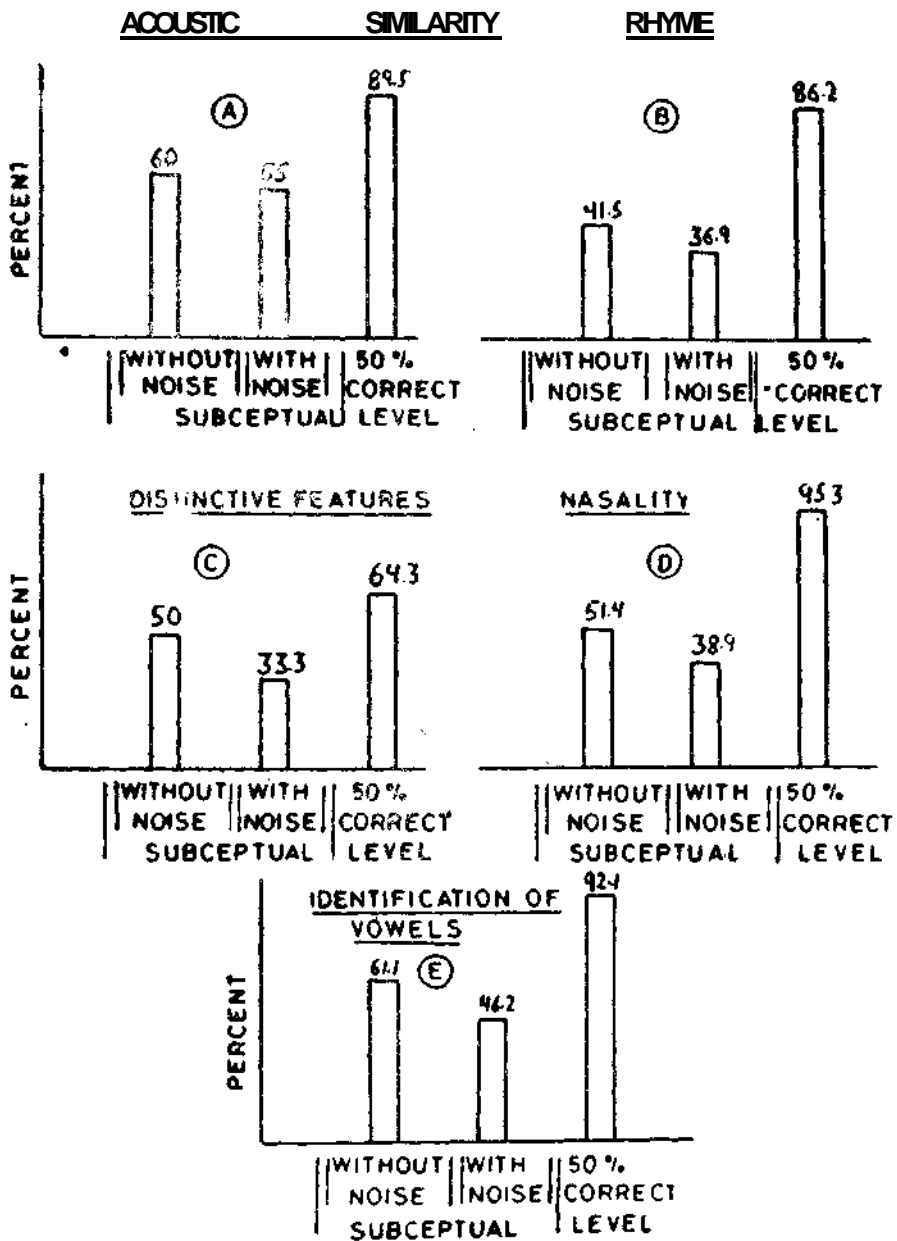
FIG : COMPARISON OFPERCENTAGE OF DIFFERENT FEATURES
PERCEIVED UNDER THREE EXPERIMENTAL CONDITIONS
(EXPERIMENTS I,II AND III)

Fig-2

of usage were identified correctly, significantly more often than words of medium and low frequency of usage. This supported the findings of Experiments I and II as well as the findings obtained in earlier studies (Howes and Solomon, 1951 ; Howes, 1954 postman and Rosenweig, 1956) which concluded that the more familiar the item, the smaller the fragment of the total stimulus needed for correct identification.

OVERVIEW

Perception of words at subceptual level can be conceptualized as involving a process where the words are initially processed as wholes, without analysis of their component letters (Massaro and Klitzke, 1977). The overall shape of the word referred to as the envelope by Bouma (1971) is resolved first and then the details of the envelope of the letter are resolved. Word perception at subceptual level seems to be involving a similar three stage process as discussed by various information processing paradigms (Liberman, 1970 ; Studdert-Kennedy, Shank-Weiller and Pisoni, 1972 : Studdert-Kennedy, 1974 a.b, ; Pisoni and Sawusch, 1975). During the first stage the auditory stage, the acoustic cues recovered in the form of the overall sound shape of the word, may be stored in the auditory memory called 'the precategorical acoustic store'. The acoustic cues are used in the second stage. called the phonetic stage, as the basis for the naming of phonetic segments. If a particular phonetic segment is not correctly identified, is may be substituted with the other which shares common features with it. During the third stage, the phonological state the phonetic segments are constrained and adjusted to fit the phonological rules of the language. A particular phoneticai sequence may be altered because it is an impossible sequence in English.

On the whole, it seems that word perception at subceptual level, requires consulting the internal lexicon and 'filling in' the missing information. Out of the various acoustically similar words available for a stimulus word in the response availability store (Conard 1965), the subject probably selects the ore which matches maximally with the obtained cues, and which also happens to be relatively a common word (Savin, 1963). The findings, in general, showed that cues such as acoustic similarity, rhyming, nasality and identification of vowel sounds were the dominant cues operating under all the experimental conditions. While some of the phonetical features were masked due to the presence of noise bringing down the overall accuracy, more number of features were perceived at 50% recognition level as a result of which a significantly higher percentage of correct than incorrect retrievals were provided. Moreover, words of high frequency of usage were identified correctly more often than words of medium

and low frequency of usage in the presence as well as in the absence of noise-at subceptual level.   Level of confidence placed in the retrieval was of 'doubt-ful' or 'guessing' nature, with more 'guessing' employed in the noise condition.

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