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THE ARTICULATION INDEX: EVOLUTION, APPLICATION & MODIFICATION.

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1. THE ARTICULATION INDEX. Within the theoretical framework developed by several of the pioneer workers(1,2,3,4,)the speech frequency scale was transformed to a new scale where frequency bands of equal width contributed equally to the Articulation Index(A.I.); this is an application of the principle underlying critical band theory(5). It is evident, from this early work, that such a transformation will be dependant on (i) the form of speech material, (ii) the test crew of talkers & listeners. Furthermore, the framework is based on the premise that the contribution of any one band of speech frequencies is independant of the contributions from other bands contained in the speech frequency range i.e.linear additivity. This premise has been challenged by three workers(6,7,8,9), although no revision to the A.I. has been forthcoming. A third aspect of the theory, concerning the "band articulation function" has been of particular interest to the author. The concept was originally formulated by Collard (10) i.e.the band articulation function applicable to a narrow speech frequency band is equally applicable to any form of speech material and testing crew.

The author examined the band articulation functions of three of the more significant contributions(1,2,3)to the A.I. evolution since Collard's work. In attempting to normalise the "sensation level" parameter of each of these functions the author chose RMS speech level as the reference quantity, the choice is however quite arbitrary. The results are shown in FIG.1, and as such the functions cannot be regarded as being equivalent or even very similar on this basis. It can be concluded therefore that the band articulation function will also be dependant upon (i) the form of speech material considered, (ii) the test crew.

Most modern publications which refer to the A.I. (e.g.11,12) present a graphical system of relationships which link sentences, words, syllables etc. to a form of the A.I; some authors qualify their relationships by accompanying the graph with a statement, "These relationships are approximate. They depend upon type of material and skill of talkers & listeners." All of these authors, and many more, obviously then recognise the subjective variables present in these relationships, but they are all assuming the mathematical form of their A.I.to be invariant, which of course it

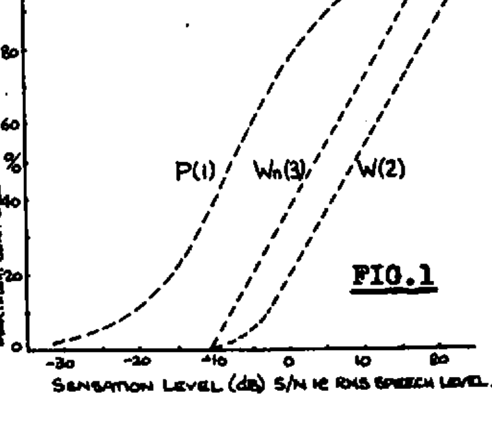

FIG.1

is not. The above has demonstrated that the functions involved in any of the forms of A.I. will vary with each new condition examined e.g.the type of speech material used will vary the form of the band articulation function. In theory then, the general practice of relating all forms of speech material to one form of A.I. is certainly not valid.

2. INTELLIGIBILITY TESTS. Two series of tests were performed to examine the use of the A.I. in predicting intelligibility in hospital wards under conditions of general ward activity with superposed levels of broad-band masking sound. Both series were performed under laboratory conditions with carefully trained subjects listening binaurally to PB-50(13)word lists in a specified background of hospital ward sounds and masking sound. Two male talkers whose speech forms were categorised as being representative of those found in this country were used to record the word lists. Over a period of six weeks each talker recorded the twenty lists of Egan(13)in the anechoic chamber of the Phonetics Department at University College London. A recording technique (14) employing an artificial head was utilised in making recordings in hospital wards. These recorded ward sounds were equalised and played back to subjects in the laboratory via specially calibrated(14)Sharpe HA-10A circumaural earphones; the technique was demonstrated to accurately reproduce intensity and time patterns at the ears of each subject in the same manner as they would have been received by the subject had he been located at the position of the artificial head in the ward during the original recording. All sound levels(masking sound, hospital sound and speech)were expressed relative to a normalised reference plane; since the laboratory listening situation attempted to reproduce hospital ward listening conditions, the author refered all sound levels to the equivalent centre-head position of the supposed listener(listener removed of course). It was necessary therefore to take particular care to ensure that all sounds which reached the subject's ears(via the circumaural earphones)were correctly equalised.

A latin square with a subjects x treatments plan was the basic experimental design chosen for each test series. Series 1 employed a design using eight trained subjects; Series 2 employed six trained subjects. All subjects underwent two weeks of training and each experienced a minimum of twelve full scale intelligibility tests before Series 1 began. Each test series was repeated using (i) a different masking sound, (ii) different word lists and talkers. The results of the two series are shown graphically in FIGS.2,3,4,&5 with logistic curves of best fit drawn through the results.

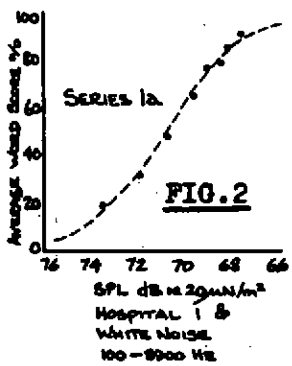

FIG.2

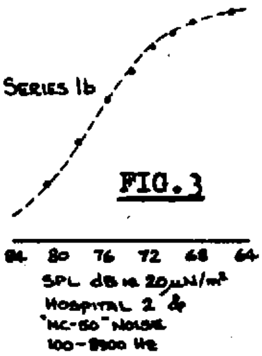

FIG.3

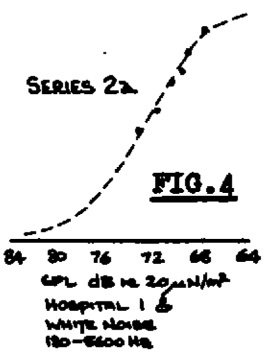

FIG.4

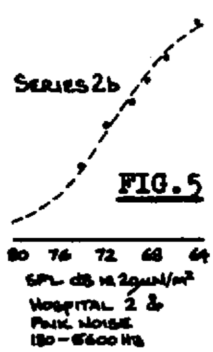

FIG.5

3. A.I. CALCULATIONS. In accordance with the 1/3-octave band procedure outlined by Kryter(17)the A.I. was calculated for the range of conditions experienced in both test series. These results are shown in FIGS.6 & 7, and curves of best fit have been drawn. In examining the pair of A.I. functions produced by each series it is apparent that there is negligible interaction

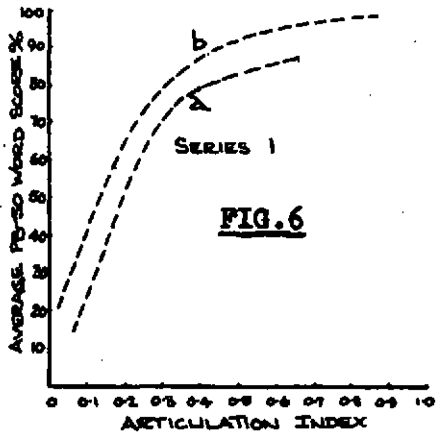

FIG.6

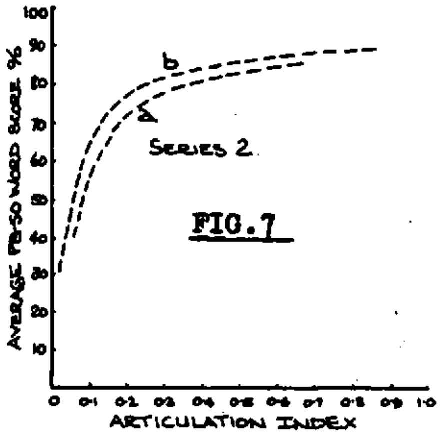

FIG.7

between the two functions i.e.each function is relatively isolated and homogeneous with respect to its neighbour. All past workers involved with the development and use of articulation theories have contented themselves with the notion that provided care is taken to maintain constant, within an articulation test series, (i) articulation test crew members and their training, and (ii) type of speech material, that the forthcoming results may be described by a single "A.I.Vs speech score" function. The results of these two series of intelligibility tests demonstrate that in addition to these constraints the final functional form also depends upon the physical characteristics of the masking sound involved in the experimental description.

4.CONCLUSIONS. Typical examples of the conclusions formed in modern opinion are to be found in the works of Kryter(11,15,16, 17)who has assumed that if "...the abilities of the talkers and listeners and the difficulty of the test materials are kept constant(11,17)," then the relationship between A.I. and intelligibility is invariant, although only under special circumstances can the A.I. be directly converted into an intelligibility score. Furthermore, the A.I. is proposed as a direct method for rank-ordering different speech communication systems within a common scale of merit; Beranek(3)in fact specifies ranges of A.I. for conditions defined as (i)unsatisfactory($0 \leqslant$ A.I. $\leqslant 0.3$), (ii) barely acceptable ($0.3 \leqslant$ A.I. $\leqslant 0.5$)and (iii)satisfactory($0.5 \leqslant$ A.I. $\leqslant 1.0$). Thus, at best, the designer can only expect to use the A.I. within a rank-ordering exersise for comparing communication systems.

The above work has demonstrated however that the relationship between A.I. and intelligibility is not invariant when applying the A.I. model to a person-to-person communication system within a hospital ward with superposed levels of broad-band masking sound, and as such its use could lead to gross errors being incurred. Moreover, the relationship has been shown to be dependent on the spectral characteristics of the masking sound involved in the experimental description of the function.

Accepting the result of this work, there are three possible paths to a solution, (a)developea new index,(b)apply secondary corrections to the existing index,(c)modify the A.I. model to include effects due to the spectral characteristics of the masking sound. Adopting(c) and considering each pair of A.I. functions shown in FIGS. 6&7 separately, there does appear to be a positive trend involved, namely, the greater the dissimilarity in spectral pressure composition of the masking sound within each pair comparison, the greater the dissimilarity between A.I. functions.

The immediate conclusion to be drawn from this illustration is that if a series of intelligibility tests were performed using, (i)a highly trained test crew,(ii)PB-50 monosyllabic words, and (iii)several different shaped broad-band masking sounds, then there would result a group, or family, of independent "A.I. Vs PB-50 word score" functions on the graphical plane.

The primary aim within any solution to this problem must therefore be to transform the results of the original A.I. computations into a form which will permit the transformed material to be used as an index within a rank-ordering system as originally intended. Such a concept might simply be realised by considering the following modification to the Richards & Archbold(1) mathematical model:

from $S = \phi[\int_0^\infty W(f)\psi(S/N)df] = \phi[\bar{P}]$,include a further factor δ which is a function of the characteristics of the masking sound within the frequency range of interest. Thus the equation could be re-written as,

$S = \phi'[\delta \bar{P}]$, where $\delta \bar{P} = A.I.^{*}$, the transformed A.I.

This model, if realisable, would enable the family of A.I. relationships to be transformed into a single-valued function and thus values of $A.I.^{*}$ could then be used as a rank-ordering index.

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