Tej K. Bhatia

A COMPUTATIONAL INVESTIGATION ON THE PERCEPTION AND ACQUISITION OF ASPIRATION

0. *Introduction.*[1]

The phenomenon of aspiration in Hindi has intrigued phoneticians and phonologists for some time. However, so far no adequate investigation of this phenomena has been made.

The earlier acoustical (i.e., perceptional) studies which have been performed on the phonetic aspects of Hindi can be grouped into two 1) acoustically-oriented, and 2) linguistically-oriented studies. In the area of acoustic studies, the most significant work was done by J. Gupta, S. Agrawal and R. Ahmad (1969) and R. Ahmad and S. Agrawal (1969). In their experiment they have revealed the significant features in the perception of Hindi consonants in normal as well as in clipped speech. For example, they pointed out that the average effect of clipping on features follows the order: 1) place; 2) nasality; 3) flapped liquids; 4) liquids; 5) continuants; 6) voicing; 7) friction; 8) aspiration; 9) affrication. i.e., the place of articulation is most important in the intelligibility of any sound, and affrication is least important. The higher the rank, the higher the intelligibility. Earlier, W. J. Black and S. Singh (1966), in their experiment with four language groups, namely English, Hindi, Arabic and Japanese, have also pointed out significant features. However, their rank order is as follows: 1) nasality; 2) place; 3) voicing; 4) friction; 5) liquid; 6) duration; 7) aspiration. The focus of the above experiments was not *aspiration*. The same is true about the linguistically oriented work done by D. P. Gandhi and S. Jaggi (1971). The present study of Hindi consonants is significant for the following reasons: first, it examines the predictive role of

[1] My thanks are due to the following for their comments on this paper: Chin-chuan Cheng and Chin W. Kim. They are, however, not responsible for any mistakes in this project.

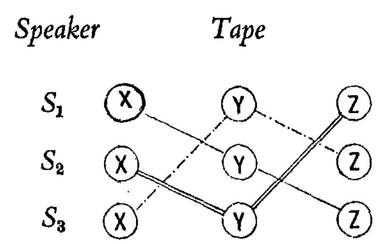
phonetic science in the light of the recent theory of aspiration propounded by C. W. KIM (1970). Second, it questions the absolute predictive power of contrastive analysis. Third, it investigates the acquisition and the development of perceptual cues in a certain amount of time by proper language training. Fourth, it presents an account of "perceptual interference" and also establishes "the hierarchy of difficulties" (or probable error) on the part of English speakers. Thus this investigation has pedagogical merit, too.

1.0. *Methodology.*

A context-free data of minimal pairs of a set of 22 consonants in initial, medial and final position was collected. The minimal pairs are of two types: 1) unvoiced unaspirated vs. unvoiced aspirated; 2) voiced unaspirated vs. voiced aspirated. Minimal pairs across the two types were also collected. The total number of items in the data is 62, with the following syllabic structures: *CVCVC* (18), *CVCV* (3), *CVC* (37), *VC* (2), *VCC* (1), *VCV* (1). Both meaningful and non-sensical, but phonologically possible, pairs of words were included in the data.

The randomized data was presented to three native speakers[2] of Hindi for recording. The recording of this data was made in the University of Illinois Phonetic Laboratory at the speed of 33/4 IPS on AMPEX Model AG 440 tape recorder.

In order to include all 62 items but to maintain the random nature of the data, the recording of each speaker (S_1, S_2 and S_3) was cut at two uniform points. Thus, the recording of each speaker was divided into three parts (*X*, *Y* and *Z*) and was joined together as shown in the diagram.



[2] I had three informants: two males (myself and Mr. Anil Arora) and one female, Mrs. Vimala Mohan. They are from Delhi, Pant Nagar (U.P.), and Lucknow (U.P.) respectively. My thanks are due to them.

This tape (which I shall call T_1) included three readings and each reading contained the voice of three informants.

The final version of the perception test tape (T_2) was prepared by copying T_1 and by inserting the necessary instructions. In T_2 sufficient space was inserted between each item so as to allow subjects enough time to mark their responses.

The test matrix[3] of 62×4 was constructed by presenting the minimal pairs of every correct item. For example, if the correct recorded item is /kər/, the test matrix was prepared in the following way: /khər/ /kər/ /gər/ /ghər/.

The perception test was relayed in the sound-isolated phonetic laboratory of the University of Wisconsin, Madison. The test-tape was played from the teacher's booth and 25 English-speaking subjects[4] heard it in their respective booths.

The IBM 360-25 was used to perform a quantitative analysis of more than 18,000 items. The test matrix was assigned codes. The integers represented the vertical position of the item. On the horizontal scale *A*, *B*, *C*, *D* represented 1st, 2nd, 3rd and 4th position, respectively.

On the data cards, all the responses were punched according to the following input format: 1) one or two integers represented the vertical position of the item; 2) *A*/*B*/*C*/*D*/ represented the horizontal position and 3) was followed by ', '4) representing the end of the reading.

2.0. *Results.*

Tables I, II and III represent the distribution of the records made by the subjects in the initial, middle, and final position respectively. The consonants given along the horizontal axis represent the sound which was perceived by the subjects and the consonants along the vertical axis indicate the consonants which were spoken by informants. For example, in Table I, the second line indicates that *kh* was spoken in the initial position. Out of 75 occurrences of *hk*, 19 times it was

[3] I am thankful to Mrs. Y. Kachru for the various suggestions in selecting data and for helping me design the test matrix.

[4] My subjects were 25 English speakers who were from various universities of the United States. In the summer of 1971 they came to Wisconsin to attend Summer School. All of them were going to leave for India to stay there for a year after the completion of intensive language training. They were well-motivated and the perception test was presented on the last day of language training.

TABLE I. *Error Matrix for Initial consonant. Maximum response number is 75.*

NR represents *No Response*
TC represents *Total Confusion*

	k	*kh*	*g*	*gh*	*c*	*ch*	*j*	*jh*	*T*	*TH*	*D*	*DH*	*t*	*th*	*d*	*dh*	*p*	*ph*	*b*	*bh*	*R*	*RH*	*NR*	*TC*	*Confusion by the native speakers*
k	53	19	1	1																			1	22	0
kh	19	55	0	00																			1	20	0
g	2	0	55	17																			1	20	3
gh	0	2	10	63																			0	12	5
c					39	31	4	1															0	36	1
ch					12	63	0	0															0	12	0
j					0	0	69	6															0	6	3
jh					5	21	14	34															0	40	19
T									38	14	16	7											0	37	2
TH									16	45	10	4											0	30	0
D									0	0	60	15											0	15	0
DH									1	1	12	61											0	14	1
t													42	32	0	1							0	33	1
th													27	48	0	0							0	27	1
d													0	0	61	8							6	14	0
dh													5	5	6	58							1	17	0
p																	55	19	0	0			1	20	0
ph																	12	63	0	0			0	12	1
b																	3	1	66	5			0	9	2
bh																	1	1	8	65			0	10	3
R																									
RH																									

TABLE II. *Error Matrix for Middle consonants. Maximum response number 75 (except dh = 150).*

NR = No Response
TC = Total Confusion

	k	*kh*	*g*	*gh*	*c*	*ch*	*j*	*jh*	*T*	*TH*	*D*	*DH*	*t*	*th*	*d*	*dh*	*p*	*ph*	*b*	*bh*	*R*	*RH*	*NR*	*TC*	*Confusion by the native speakers*
k	48	26	0	0																			1	27	1
kh	19	56	0	0																			0	19	1
g	1	0	66	8																			0	9	6
gh	2	7	3	62																			1	13	2
c					32	40	1	0															2	45	1
ch					7	68	0	0															0	7	0
j					2	0	60	13															0	15	0
jh					4	23	10	38															0	37	19
T									55	16	2	0											2	20	2
TH									24	51	0	0											0	24	0
D									1	0	50	23											1	25	0
DH									2	0	12	61											0	14	2
t													42	32	0	1							0	33	1
th													20	54	0	1							0	21	2
d													0	0	69	6							0	6	0
dh													2	4	17	127							0	11.5	4
p																	57	0	17	1			0	18	2
ph																	10	65	0	0			0	10	0
b																	0	1	63	10			1	12	0
bh																	1	3	11	60			0	15	0
R																					47	28	0	47	
RM																					25	50	0	25	

TABLE III. *Error Matrix for Final consonants. Maximum response number = 75 (except RH = 150).*

NR = No Response
TC = Total Confusion

	k	*kh*	*g*	*gh*	*c*	*ch*	*j*	*jh*	*T*	*TH*	*D*	*DH*	*t*	*th*	*d*	*dh*	*p*	*ph*	*b*	*bh*	*R*	*RH*	*NR*	*TC*	*Confusion by the native speakers*
k	34	39	0	2																			0	41	6
kh	14	60	1	0																			0	15	1
g	1	2	55	17																			0	20	17
gh	0	0	38	37																			0	38	34
c					42	30	2	0															1	33	26
ch					13	62	0	0															0	13	2
j					3	1	44	27															0	31	16
jh					1	0	25	49															0	26	11
T									34	35	2	3											1	41	6
TH									13	61	0	1											0	14	2
t													43	26	5	0							1	32	13
th													5	70	0	0							0	5	0
d													2	0	46	27							0	29	30
dh													1	1	16	57							0	18	22
p																	31	36	5	2			1	44	9
ph																	1	74	0	0			0	1	8
b																	0	0	30	44			1	45	17
bh																	1	12	7	55			0	20	11
R																					41	33	1	34	39
RH																					39	110	5	20	13

perceived as *k*; 55 times correctly as *kh*; and zero times as *g* and *gh*. Once there was no response. Thus, out of 75 occurrences of *kh*, 55 times it was correctly responded and 20 times it was confused.

The diagonal represents the correct responses given by the subjects while readings on the left or right of it denote errors. In the tables, *NR* stands for "No response", and *TC* stands for "Total Confusion" which is the sum of all the readings which appears on the left or right of the diagonal plus *NR*.

The results presented in these Tables (I, II and III) are summarized below:

(1) In all the positions, unvoiced unaspirated consonants, such as *k*, *c*, *t*, *T* and *p* are mistaken more than unvoiced aspirated consonants. In medial position the only exception is *TH*. *TH* is more confused than *T*.

(2) In initial and medial positions, voiced aspirated consonants are more confused than voiced unaspirated consonants. The exceptions are *DH* and *gh* in initial position.

(3) In contrast to initial and medial position, the confusion in voiced unaspirated consonants is more than in voiced aspirated consonants in final position. The only exception is *g*.

(4) The rate of confusion in the palatal series is much higher than the rate of confusion which took place in other series.

Thus, the above results indicate that subjects reacted differently in final position and in initial and medial position in the case of voiced aspirated consonants.

Table IV points out the first and second probable errors and presents a clear picture of mistakes made by the subjects. The probable error is drawn from the readings of Table I, II, and III. First probable error refers to the most frequent mistake while the second probable error to the next most frequent mistake. For example if *g* is 5 times mistaken for *k* and 3 times mistaken for *kh*, then the first probable error for *g* will be *k* and the second probable error will be *kh*.

In some cases there is a probability of three errors but the third one is the least confused; that is why it is omitted in Table IV. The most important error is the first probable error. The error which is responsible for 33 % or more of the confusion is marked as significant error and is indicated by a line under it and if 5 % or less confusion is caused by an error, that error is considered to be insignificant and is indicated by a star.

TABLE IV. *Probable error matrix (for* TABLE I, II, *and* III) *for initial, middle and final consonants.*

Consonants	First Problable Error Initial position	First Problable Error Middle position	First Problable Error Final position	Combined Error	Second Probable Error Initial position	Second Probable Error Middle position	Second Probable Error Final position
k	*kh*	*kh*	*kh*	*kh*	*g/gh**		*gh**
kh	*k*	*k*	*k*	*k*			*g**
g	*gh*	*gh*	*gh*	*gh*	*k**	*k**	*kh**
gh	*g*	*kh*	*g*	*g*	*kh**	*g*	
c	*ch*	*ch*	*ch*	*ch*	*j*	*j**	
ch	*c*	*c*	*c*	*c*			
j	*jh*	*jh*	*jh*	*jh*		*c**	*c**
jh	*ch*	*ch*	*j*	*ch/j*	*j*	*j*	*c**
T	*D*	*TH*	*TH*	*TH/D*	*TH*	*D**	*DH**
TH	*T*	*T*	*T*	*T*	*D*		*DH**
D	*DH*	*DH*		*DH*		*T**	
DH	*D*	*D*		*D*	*T/TH**	*T**	
t	*th*	*th*	*th*	*th*	*dh**	*dh**	*d*
th	*t*	*t*	*t*	*t*		*dh**	
d	*dh*	*dh*	*dh*	*dh*			*t**
dh	*d*	*d*	*d*	*d*	*t/th*	*th**	*t/th**
p	*ph*	*b*	*ph*	*ph*		*bh**	*b*
ph	*p*	*p*	*p**	*p*			
b	*bh*	*bh*	*bh*	*bh*	*p*	*ph**	
bh	*b*	*b*	*ph*	*b/ph*	*p/ph**	*ph**	*b*
R		*RH*	*RH*	*RH*			
RH		*R*	*R*	*R*			

* Represents insignificant error (CONFUSION is 5 % or less)

Underlined consonants are significant errors (CONFUSION is 33 % or more)

The probable error in initial, medial and final position is determined from Tables I, II and III respectively. And then on the basis of significance and frequency of the error in all three positions, a combined error is determined. The two other results which can be drawn from Table IV are given below:

(5) First probable error indicates that the confusion occurred most frequently between the consonant classes which can be distinguished by a single feature, i.e., either by aspiration or by voicing.

The other indirect result which can be arrived at is that there is not a single example in the first probable error which indicates that the confusion took place between consonant classes which can be distinguished by two features, i.e. voicing and aspiration. Second probable error record shows that such type of confusion did take place but it was insignificant.

TABLE V. *Rank Order of the Perceptually Confused Consonants.*

One Feature	Initial Position	Middle Position	Final Position	Combined Rank Order
[— aspirate]	1	1	1	1
[+ aspirate]	2	2	2	2
[+ voiced]	3	3	3	3
[— voiced]	4	4	4	4
Two Features				
[+ voiced, + aspirate]	1	1	2	1
[— voiced, — aspirate]	2	2	1	2
[+ voiced, — aspirate]	4	3	2	3
[— voiced, + aspirate]	2	4	4	4

Table V presents the rank ordering of features. The rank ordering has been expressed in terms of one feature as well as in two features. The rank ordering of the consonants in determined by adding the total number of confusions which took place in the perception of those consonants. First, the ranks have been established according to initial, medial and final position, i.e. information transmitted by Tables I, II, and III, respectively. For example, if any consonant is confused the least then rank 4 is assigned. On the other hand, if any consonant is confused the most in any position, it is assigned rank 1. Second, by summing up the ranks in all the positions the combined rank is determined. If the sum of all the three positions is least, rank 1 is assigned and if it is highest, rank 4 is allotted. The rank of 1 indicates the highest number of confusions and the rank of 4, the least number of confusions.

The labels in Table v are explained below:

(a) [— Aspirate] indicates that the the consonants such as *k* and *g* are mistaken for *kh* and *gh* respectively.

(b) [+ Aspirate] presents the opposite case of (a).

(c) [+ Voiced] indicates that voiced consonants such as *g* and *gh* were confused for unvoiced consonants *k* and *kh* respectively.

(d) [— Voiced] shows that confusion was caused as a result of the addition of voicing, i.e. unvoiced consonants such as *k* and *kh* were mistaken for voiced consonants *g* and *gh* respectively.

Rank-ordering in terms of two features is presented below:

(a) $\begin{bmatrix}+\text{ voiced}\\+\text{ aspirated}\end{bmatrix}$ refers to the reverse case of(b).

(b) $\begin{bmatrix}-\text{ voiced}\\-\text{ aspirated}\end{bmatrix}$ means unvoiced unaspirated consonants are mistaken for voiced aspirated, i.e. consonants like *k* are mistaken for *gh*.

(c) $\begin{bmatrix}+\text{ voiced}\\-\text{ aspirated}\end{bmatrix}$ expresses that the consonants such as *g* and *c* are mistaken for *kh* and *ch* respectively.

(d) $\begin{bmatrix}-\text{ voiced}\\+\text{ aspirated}\end{bmatrix}$ shows that unvoiced aspirated consonants were mistaken for voiced unaspirated consonants such as the confusion of *ch* for *j*.

The results which can be drawn from Table v are given below.

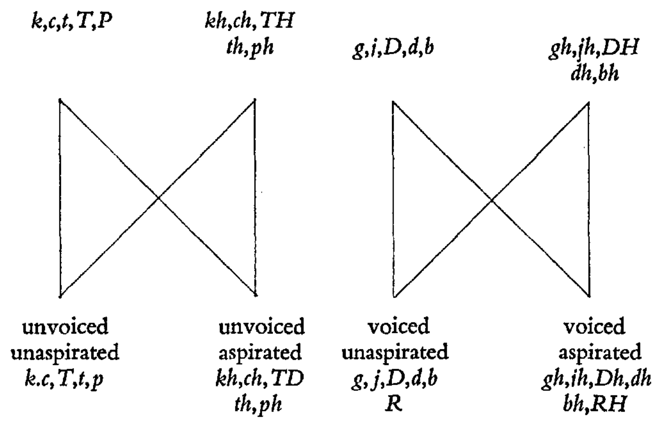
(6) The confusion of unaspirated in all the positions is the highest of all.

Consequently, [— aspirated] has the highest number one while [+ aspirated] has a lower rank. The confusion which took place in terms of the two features is insignificant except for the one which has rank one.

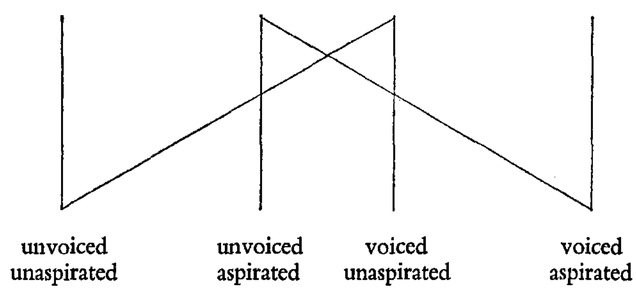
TABLE VI. *The two types of interaction is shown below (on the basis of First Probable Error):*

1. *between unaspirated and aspirated consonants.*
2. *between voiced aspirated and unvoiced aspirated consonants and unvoiced unaspirated and voiced unaspirated consonants.*

For example: Confusion /k/ and /kh/ (Diagonal indicates confusion of /g/ for /gh/ etc. and vice versa)



Confusion of /T/ for /D/ (/bh/ was mistaken for /ph/)



1. The straight lines indicate the correct-recognition of consonants.
2. Diagonals show confusion of sounds.

3.0. *Discussion.*

A contrastive analysis of a fragment of Hindi and English sounds will predict the following bilingual interference:

(1) In English, only unvoiced aspirated consonants occur in initial position so it is likely that an English speaker will replace unvoiced

unaspirated consonants by unvoiced aspirated ones. As a results of this, the perceptual confusion of unvoiced unaspirated consonants will be more.

My results mostly agree with the above statement.

(2) In medial and final position unvoiced aspirated consonants do not occur in English. Therefore, such consonants are likely to be replaced by unvoiced unaspirated consonants unless these syllables are stressed.

My results partially agree with this prediction. In medial position unvoiced unaspirated consonants are preceded by *su* or *ku* *CV*-type prefix. The stress is carried by the second syllable; that is why unvoiced unaspirated consonants are mistaken more in medial position.

(3) The voiced aspirated consonants will be mistaken more than voiced unaspirated in all the positions because they are not present in English.

My results indicate that the conclusion of contrastive analysis is relevant. The subjects confused voiced aspirated consonants more than voiced unaspirated in initial and in medial position. But in the final position the situation changes completely.

In a recent study an attempt has been made to explain aspiration in terms of " voicing lag " (see L. LISKER and A. ABRAMSON, 1964; C. W. KIM, 1970).[5] Aspiration is explained in terms of two reference points, i.e. (a) release of closure of a stop; and (b) the onset of voicing.

Since in final position one reference point, i.e. onset of voicing is lost, thus, the theory implies that aspiration will be neutralized in word final position. In other words, aspirated sounds will be pronounced as unaspirated sounds in final position, and as a result, aspirated sounds will be perceived as unaspirated sounds in the word final position.

In final position my results indicate that aspirated consonants are recognized more than unaspirated ones. On the contrary, unaspirated consonants are mistaken more frequently.

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[5] Kim's explanation of aspirations differs from Lisker and Abramson in terms of underlying control mechanism. Kim agrees that aspiration is laryngeally controlled. But what is controlled by the laryngeal muscles in the case of aspiration is not the timing of glottal closing (Lisker and Abramson's view) but the size of the glottal opening.

Manjari and John Ohala refute Chomsky and Halle's claim that heightened sub-glottal air pressure is a necessary characteristic of all aspirated consonants. According to them, during *h* and upon the release of the aspirated stops there occurs a moment when there is no oral constriction and when the glottal resistance is markedly lower than that of normal voicing. Given such lowered resistance to the lung air, the air naturally rushes out in great volume, and consequently the air pressure just below the glottis is momentarily lowered.

My results get further support from another experiment which I performed with native speakers of Hindi. The results of that experiment showed the same directions.

The analysis of my results in final position raises two questions: 1) Why are aspirated (voiced and unvoiced) stops recognized more than unaspirated stops by the English speakers, while these sounds don't exist in English in final position? 2) Why are unaspirated consonants confused more although such sounds are present in English?

The answer to the first question is that in the pronunciation of aspirated consonants of Hindi a sort of strong final release is present which helps English speakers to perceive aspirated consonants more accurately in final position.

As for question 2, two possibilities can be presented as an answer. 1) The unaspirated consonants in word-final position are released, and the release causes the English speakers to interpret them as aspirated. 2) The nature of pronunciation (of native speakers) can be responsible for the perceptual confusion of those consonants which are common to both Hindi and English. W. J. BLACK and S. SINGH's (1966) experiment shows that when a set of data which included the identical sounds of languages was presented by native speakers to other native speakers and to non-native speakers, the confusion in the latter case was relatively high. It seems that the nature of pronunciation is responsible for the perceptual confusion of identical sounds.

In my results, I noticed certain exceptions. Interestingly enough, I found similar exceptions in experiments with native speakers. This shows that these exceptions seem to be related with some underlying phenomenon which is operating not only in the case of native speakers of English but also in the case of native speakers of Hindi.

Below, I will discuss the exceptions and will propose some explanations.

(1) In the case of unvoiced unaspirated consonants the only exception was present in the retroflex consonant in medial position, i.e. *T* is less confused in medial position. However, it is negligible.

(2) The exceptions, in the case of voiced aspirated consonants, occur in the retroflex and velar consonants. In initial and medial positions, *DH* is less confused and *gh* in the initial position is less mistaken too, while other voiced aspirated consonants are more confused in these two positions.

Now two questions arise: 1) Is this distinction parallel to the distinction which the native speakers of Hindi maintain? 2) Can they maintain this distinction because of a relative strength of aspiration present in such unaspirated and aspirated consonants?

It seems that English speakers maintain the latter type of distinction. The retroflex are considered to be [+ tense] and velars, because of their [+ back]ness inherit some aspiration.

There is another exception in final position. In final position all voiced aspirates are recognized more than voiced unaspirates. But *gh* is an exception.

Velar voiced aspirated consonant *gh* should not be mistaken more than its unaspirated counter-part, because of the following reasons: First, it carries a final release since it is an aspirated consonant. Second, it has a relatively higher degree of aspiration than dental, bilabial and palatal consonants. At this point it appears to me that either voiced aspirated consonant *gh* behaves like unaspirated in final position and loses its final release as well as higher degree of aspiration simultaneously (further research with acoustic instruments is needed to support this); or this exception points towards a psychological process of " overcompensation " which is going on in the subject's mind, i.e. English speakers, like the native speakers of Hindi, realize that aspiration is the most characteristic phonological feature of Hindi. That is why they sometimes substitute aspirated sounds for unaspirated and, as a result, we may get exceptions in cases such as *gh*. The shortcomings of this proposal can be easily noticed since the question arises why the phenomenon of " overcompensation " fails to operate upon other segments. Similarly, the first hypothesis can be questioned on the ground that if all other unvoiced aspirated consonants as well as voiced aspirated consonants maintain their own identity (i.e. 1) final release; 2) final-release and relatively high degree of aspiration, respectively) then why does only *gh* lose it in the final position? Instrument measurements are needed to answer this question.

4.0. *Comparison of this Investigation with Gandhi's and Jaggi's Research.*

Gandhi's and Jaggi's investigation of Hindi consonants also shows two results with regard to aspiration. First, in all the positions aspirates are mistaken more than unaspirates by English speakers. Second, unaspirates are substituted for aspirated sounds.

My results show disagreement with their results in the final position only, since my results show that the intelligibility of aspirated consonants is more than unaspirated, with the exception of *gh* in final position.

My results completely agree with their second finding. The disagreement in the final position can be caused because of several reasons: First, in their study aspiration is not the focus; thus, their results have been determined on the basis of a very restricted amount of data. Second, from their experiment it is not clear which kind of data was used to perform such an experiment. Third, such disagreement can happen because of their inaccurate recording and listening conditions. Lastly, it may depend on the language training of the subject.

It was not mentioned in their study whether the second syllable was stressed in the middle position or not. In such a situation, it is hard to conclude whether my results agree or disagree with their findings.

5.0. *Summary*.

The following conclusions can be drawn from the above discussion. First, unvoiced unaspirated consonants are more confused than unvoiced aspirated consonants in all positions. Second, voiced aspirated consonants behave differently: 1) in initial and medial position; and 2) in final position. In initial and medial position they are mistaken more while they are better recognized in final position. Third, the confusion occurred primarily between the consonant classes which can be distinguished by a single feature, i.e., either by aspiration or by voicing. Fourth, unaspirated segments were more frequently confused than aspirated ones. $\begin{bmatrix} -\text{voicing} \\ +\text{aspiration} \end{bmatrix}$ has the lowest rank, i.e. the least confusion took place in the perception of these segments. Fifth, exceptions are present only in the retroflex or velar series. In such consonants (voiced) the degree of aspiration present is relatively high. It seems that voiced unaspirated consonants of velar and retroflex series possess almost equal amounts of aspiration which is present in palatal, dental, and bilabial aspirated (voiced) consonants, and that aspirated consonants of velar and retroflex series preserve higher degree of aspiration than the aspirates of the palatal, dental or bilabial series. This is a highly tentative conclusion since it lacks empirical support. Sixth, after undergoing an intensive Hindi instruction of a semester, motivated students can develop perceptual cues for aspiration. They can hear aspiration in more than 50 % of the cases. Lastly, the rate of confusion in the palatal series is much higher than the rate of confusion which takes place in other series.

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