DURATION MODEL FOR URDU USING
THE SUM OF PRODUCTS MODEL

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Dedicated to my family

Vita

Sadaf Nawaz received a Bachelor of Science degree in Computer Science from National University of Computer and Emerging Sciences (NUCES), Lahore, in 2003. In 2004, she worked as a Development Engineer in the Text to Speech Synthesis team at EGD-CRULP NUCES, Lahore. The research in this dissertation was carried out from 2004 to 2005.

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Sadaf Nawaz

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1. Introduction

The importance of man-machine interface has increased over the years and the area is promising a great potential for widespread use in the coming years. Speech is one of the crucial elements of man-machine interfaces. The three major areas based on evolving speech technology are Speaker recognition systems, Speech recognition systems and Speech Synthesis Systems (Voice Response systems or (Text To Speech (TTS) Systems). (Sëayli, Ë; 2002)

The most important parameter in the quality of the speech systems is intelligibility. The quality and naturalness of the utterance produced by the TTS system has a direct effect on the usefulness of the TTS system. Experiments based on acoustic analysis have shown that the naturalness and intelligibility of the utterance produced by TTS systems greatly depends upon the prosodic features duration and intonation. Having correct parameters for duration and intonation, the naturalness of the speech produced can be greatly improved. Precise information about the parameters greatly improves the efficiency of the speaker and speech recognition systems.

Recent work done on Urdu speech synthesis has relied on using either foreign language duration models or using default durations. Using default durations results in a monotone speech with each speech unit having the same duration in all contexts, whereas using some other languages' duration model doesn't sound natural either as each language has its own chemistry when it comes to assigning durations to its sub segments. This thesis is a step towards modeling the actual durational phenomenon of Urdu language and hence accurate duration prediction for the speech systems.

In natural speech, the durations of phonetic segments are strongly dependent on the contextual and positional factors. For synthetic speech to sound natural, the module for computing segmental durations (the duration module) must mimic these contextual factors as closely as possible. This dissertation is focused upon finding the percentage effect of these factors for Urdu, to explore the durational trends and to make a duration model for Urdu that precisely predicts the duration of a phone in the particular context.

The two facets of segmental duration that obstruct the construction of a duration system are the interaction between the factors and the scarcity of training data. In order to study the behavior of a language in context of duration, the experiment should be set up carefully in order to capture as much of the data sets as possible, but still the rare occurrences remain uncaptured. In this dissertation an extensive study of the trends of duration exhibited by Urdu consonants and vowels under controlled single word environment are studied and presented. A duration prediction model based on the sum of products model (SOP) is then made based on this durational study. This thesis starts with a brief introduction to the issues related to duration modeling and how different duration models cope with them. An overview of the techniques used for modeling segmental durations is also included.

2. Duration Modeling

Very little is known about the underlying process responsible for speech timing, and speech timing can only be predicted up to a point from text. (Sëayli, Ë; 2002). Owing to this, duration prediction for TTS systems remains a challenging area in speech science. For example the F0 peak value depends on several factors like stress, phrasal location, vowel identity etc (Santen, J; Sproat, R; 1998). Identifying these factors and predicting their correct values requires the following key issues to be considered:

1. Which factors are relevant for the given variable?
2. How do the factors in combination affect the variable?

Thinking of TTS duration component as a black box, inputs to the black box can be described as discrete vectors, for example the input vector to the TTS duration component can be a vector of the form

$$f = < /o/, \text{ stressed, accented, } \ldots, \text{ word final} > \qquad (1)$$

This vector represents the properties of phoneme /o/ with properties stressed, accented and in word final position. Each component of such a vector is a level on a factor, where each factor can be identified as a set . For example the stress and word position factors can be identified as

$$\text{Stress} = \{1 \text{ stress}, 2 \text{ stress}, \text{unstressed}\} \qquad (2)$$

$$\text{Word position} = \{\text{word-initial}, \text{word-middle}, \text{word-final}\} \qquad (3)$$

Denoting factors as $F_1, \ldots F_{N,}$ the set of all vectors S forms a factorial space

$$S = F_1 \times F_2 \times \ldots \times F_N \qquad (4)$$

The task of the duration or timing component is to assign segmental durations to inputs of the type in equation 1. In other words the duration component maps vectors onto real numbers, **R**

$$\text{DUR: } S \longrightarrow \textbf{R} \qquad (5)$$

3. Properties of Segmental duration data

Segmental duration is among the aspects of speech, which a text to speech system must infer from text. Two challenges are faced when trying to predict segmental duration from text. The first challenge is that the feature space has an extremely uneven frequency distribution. The feature space is the product of all factors $F1 \times \ldots \times Fn$, where a factor $F1$ is defined as a partition of mutually exclusive and exhaustive possibilities such as {1_stressed, 2_stressed, unstressed}. The linguistic space is the subset of vectors that actually occur in the language, and is significantly smaller than the feature space. Thus as a result the training samples often include a very small and uneven subset of the feature space. However it has been shown (Santen .J; 1994) that text samples as small as few sentences are guaranteed to contain exceptionally rare feature vectors.

The second challenge is that the factors interact. By interaction we mean that magnitude of an effect is not constant but is affected by other factors. These properties of the segmental duration data are discussed below:

3.1. Coverage Issues

Construction of a training database having an adequate coverage of the linguistic space is a very difficult task. This is due to the large number of factors that have major effects on segmental duration, for example for vowels at least eight factors are known to have a significant impact. Each of these factors will have several levels, this leaves us a with a large feature space for studying the effect of vowel durations. In order to construct a training database, the to-be-read text must be generated to cover these feature vectors, but the lopsided of these vectors in text makes it very difficult to have complete coverage. In (Santen .J; 1992) it has been shown that "even a small sample of one dozen sentences consisting of a few hundred phonetic segments is almost certain to contain at least one feature vector that occurs less than once in a million segments. Hence, the duration system cannot ignore exceptionally rare feature vectors. " To obtain adequate coverage a greedy algorithm proposed by J.P.H Van Santen can be used, however it also does not guarantee a balanced data set.

Once having text with adequate coverage, the speech recordings should be done at a controlled speech rate. Speakers have a general tendency to talk faster in longer sentences. Multiple recordings need to be done to cater with this variability of the speaking rate, however deviations from the average speaking rate still remain. The only way to counter these problems is to have multiple data points for each feature vector but this results in a significant increase in the amount of recording.

In practice the data used for duration modeling does not has all the feature vectors but the distribution is such that they provide durations that are accurate for some vectors, marginally accurate for a larger number of vectors, and are lacking duration information for a still larger number of vectors, these are the rare vectors of language that are not easy to capture as it drastically increases the duration data.

3.2. Interactions

Interactions among factors pose problems for models to capture the effect of any factor. This applies to the simplest sum-of-products models, i.e. the additive and multiplicative models.

Factors are said to interact when other factors modulate the effect of one factor. Two types of factors exist, ordered factors and categorical factors.

Ordered factors are the factors whose effects are always in the same direction. Interactions involving ordered factors are normally well behaved in that their effects are amplified by other factors but not reversed or otherwise. Many factors are ordered for example, in spoken English it is difficult to imagine that two conditions differing only in syllabic stress and having longer vowel duration in the unstressed condition than in the stressed condition.

The advantage that these ordered factors give is that they form the basis for interpolation. Assume for example, that for vowel duration factor the following factors are ordered

- Within-word position (word-final $>_2$ other)
- Prevocalic consonant (voiced stops $>_4$ other)

Then vowel duration in "bead" should be longer in duration than "feed". More generally a set of factor-wise orders together define a partial order over the feature space. Having so if some feature vectors are missing in the training data, chances are that at least some of each subset is present, which can then be used to predict the duration of the missing vectors.

Not all factors that apply to vowel duration are relevant for consonants. Consider the stress factor for vowels and for intervocalic consonants, obviously the "stress levels of the immediately surrounding vowels" has a great impact for intervocalic consonants but has no significance for vowels. So the sum of products model made for vowels is not applicable in this case. In general there are categorical distinctions in the feature space that cannot be bridged by sum of products models because either different factors apply, factors require different restrictions, factors have different effects with respect to categorical distinction. Thus the sums of products models here have to be different for both the categories. Such factors that belong to different categories are called **categorical factors**. A category tree is shown in Figure 1.
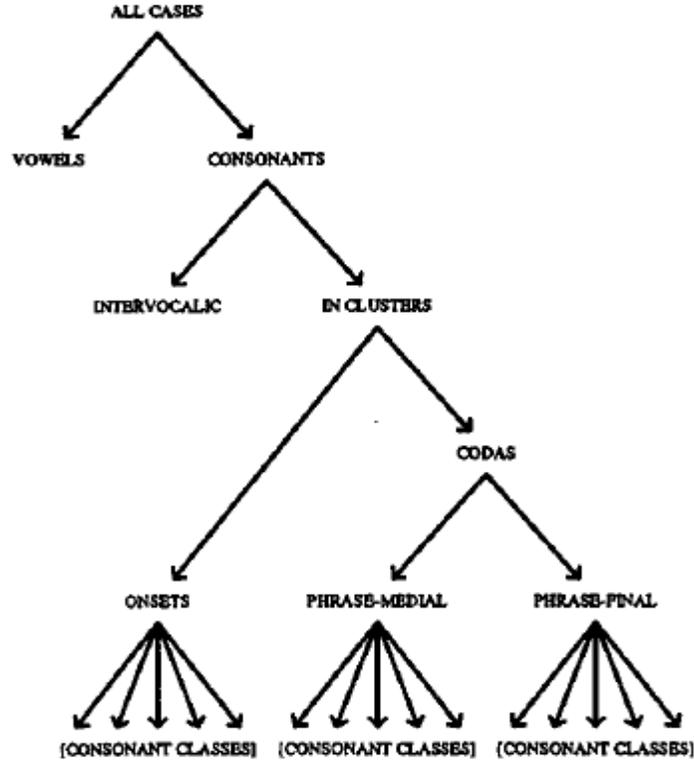
Figure 1: Categorical distributions made in duration system

4. Duration modeling techniques

4.1. Lookup table

Lookup table is the simplest statistical model used for duration prediction. It consists of assigning a value to each possible combination of parameters of the descriptor vector (Febrer, A. et. al.). These values are found using the training data and finding the base average duration for each feature vector.

This approach however cannot be generalized and requires that the training database should cover the feature space completely in order to find the average durations for each feature vector. (Sëayli, Ë; 2002)

4.2. Additive and multiplicative models

Duration prediction with additive model is done according to the formula (Sëayli, Ë; 2002):

$$DUR\ (f) = D_1\ (f_1) + D_2\ (f2) + \ldots + D_N\ (f_N) \qquad (6)$$

This mapping is usually done in multiple stages. Thus for each i, first the vector Fi is mapped onto Ri, and the combinations of these outputs is mapped onto the final output by adding these numbers. This is the fundamental concept of the additive model. This process can be represented as:

$$D_i\ :\ F_i \longrightarrow R \qquad (7)$$

And the resulting values are combined to get the final duration output as in eq 6:

In the additive model represented by equation 6, each D_i is a parameter vector, whose number of components is equal to the number of levels of factor F_i. For example if F_1 is the Stress factor, and D_1 (1 stressed) = 15ms, D_1 (2 stressed) = 6 ms, and D_1 (unstressed) = -20ms, then in this case the effect is that 1 stressed vowels are 35ms longer than unstressed vowels. These parameter values can be estimated from data and represent the effect of Stress factor in this particular case.

There could be more than one per-factor mapping. For example for i = 1,2,3, in addition to F_i we have $E_i : F_1 \longrightarrow R$ and the combination rule is given by:

$$DUR(f) = D_1\ (f_1) + D_2\ (f2) + D_1\ (f_1) \times D_3\ (f_3) \qquad (8)$$

It is evident that determining the magnitudes is no longer straight forward as now the factors interact. If the third factor is phone identity then the effects of stress are given by:

StressEffect(/e/) = [D_1 (1 stressed) + E_1 (1 stressed) × D_3 (/e/)] −

$$[D_I \text{ (1 unstressed)} + E_I \text{ (1 unstressed)} \times D_3 \text{ (/e/) }] \tag{9}$$

$$\text{StressEffect(/i/)} \quad = \quad [D_I \text{ (1 stressed)} + E_I \text{ (1 stressed)} \times D_3 \text{ (/i/) }] -$$
$$[D_I \text{ (1 unstressed)} + E_I \text{ (1 unstressed)} \times D_3 \text{ (/i/) }] \tag{10}$$

The stress effects will be different for these two vowels, meaning that the stress factor and vowel identity factor interact.

For interactions in the multiplicative sense the "+" is replaced by "×" and "÷". In multiplicative interactions, the effects are measured in fractions rather than millisecond amounts (Santen, J; Sproat, R; 1998).

A big advantage of additive systems is that the needed coverage of feature vectors in training database is much lower than others i.e. lookup table models where complete coverage is required. Additive and multiplicative models are used frequently in TTS systems because of relatively simple parameter estimation (Sëayli, Ë; 2002).

4.3. Klatt's model

The Klatt duration rules are a standard in speech synthesis. Based on a large number of experiments modifications from a base duration of all the phones are describe by a set of 11 rules.(Girija.P, Sridevi.A) The Klatt model assumes that

- Each phonetic segment type has an inherent duration that is specified as one of its distinctive properties.
- Each rule tries to effect a percentage increase or decrease in the duration of the segment
- Segments cannot be compressed shorter than a certain minimum degree.

The model is represented by the following formula:

$$\text{(INDUR - MINDUR)} \times \text{PRCNT}$$

$$\text{DUR} = \text{MINDUR} + \frac{\qquad\qquad\qquad\qquad}{100} \qquad (11)$$

Where

INHDUR = inherent duration of the segment

MINDUR = minimum duration of the segment if stressed

PRCNT = percentage shortening determined by applying rules determined from experiments (i.e. phrase final lengthening, polysyllabic shortening).

This equation can be rewritten as:

$$\text{DUR}(\,V, C, P\,) = S_{1,1}(V)\,S_{1,2}(C)\,S_{1,3}(P) + S_{2,1}(V) \qquad (12)$$

Here V denotes the vowel identity factor, C the class of postvocalic consonant (voiced vs. voiceless), P the phrasal position factor, $S_{2,1}(V)$ is the inherent duration of the vowel, $S_{1,1}(V)$ is the net duration defined as the difference between the inherent duration and the minimum duration and $S_{1,2}(C)$ and $S_{1,3}(P)$ are constants tied to the post vocalic consonant and the phrasal position. $S_{i,j}$ is a parameter vector, each parameter corresponding to a level on the j-th factor.

The rules presented by the Klatt model are applied successfully starting with initial (or "inherent" segment duration. The rules proposed by Klatt are:

1. PAUSE INSERTION RULE: Insert a brief pause before each sentence-internal main clause and at other boundaries delimited by an orthographic comma (Goldman-Eisler, 1968; Cooper *et al*., 1978).

2. CLAUSE-FINAL LENGTHENING: The vowel or syllabic consonant in the syllable just before a pause is lengthened (Gaitenby, 1965). Any consonants in the rhyme (between this vowel and the pause) are also lengthened (Oller, 1973; Klatt, 1975a).

3. PHRASE-FINAL LENGTHENING: Syllabic segments (vowels and

syllabic consonants) are lengthened if in a phrase-final syllable (Klatt, 1975a). Durational increases at the noun-phrase/verb-phrase boundary are more likely in complex noun phrase or when subject-verb-object order is violated; durational changes are much less likely for pronouns (Harris *et al*., 1981). The lengthening is perceptually important (Lehiste *et al*., 1976; Umeda and Quinn, 1981).

4.   NON-WORD-FINAL SHORTENING: Syllabic segments are shortened slightly if not in a word-final syllable (Oller, 1973). [This rule is disputed by Umeda (1975).]

5.   POLYSYLLABIC SHORTENING: Syllabic segments in a polysyllabic word are shortened slightly (Lehiste, 1975a). [This rule is also disputed by Umeda (1975).]

6.   NON-INITIAL-CONSONANT SHORTENING: Consonants in non-word-initial position are shortened (Klatt, 1974; Umeda, 1977).

7.   UNSTRESSED SHORTENING: Unstressed segments are shorter and more compressible than stressed segments (Fry, 1958; Umeda, 1975, 1977; Lehiste, 1975a).

8.   LENGTHENING FOR EMPHASIS: An emphasized vowel is significantly lengthened (Bolinger, 1972; Umeda, 1975).

9.   POSTVOCALIC CONTEXT OF VOWELS: The influence of a postvocalic consonant (in the same word) on the duration of a vowel is such as to shorten the vowel if the consonant is voiceless (House and Fairbanks, 1953; Peterson and Lehiste, 1960). The effects are greatest at phrase and clause boundaries (Klatt, 1975a).

10.   SHORTENING IN CLUSTERS: Segments are shortened in consonant-consonant sequences (disregarding word boundaries, but not across phrase boundaries) (Klatt, 1973a; Haggard, 1973).

11.   LENGTHENING DUE TO PLOSIVE ASPIRATION: A stressed vowel or sonorant preceded by a voiceless plosive is lengthened (Peterson and Lehiste, 1960).

When the Klatt model was introduced it was also perceptually evaluated in an experiment. It was found that durations predicted by the model were of equal naturalness as the original durations from the reference speaker (Carlson. R).

Klatt model is a sum of products model (explained later) as is evident from equation 12. The Klatts' model is arguably the best duration model and has been implemented by MITTalk and also has been adapted for other languages (Santen .J; 1994).

4.4. Sum of products model

The sum of products model represents the duration for phonemes/context combination described by the feature vector f as:

$$DUR(f) = \sum_{i \in k} \prod_{j \in Ii} S_{i,j}(f_i) \tag{13}$$

Here k represents the set of indices, each of which corresponds to a product term. The sum of products models capture the phenomenon of directional invariance, according to which the effects of a factor, like stress or prepausal position have always effects on the same direction. It was observed in an experimental procedure that the mean duration of non-prepausal /O/ is longer than

/o/. That is holding all else constant, the same vowels in prepausal position had longer duration values.

The effects of sentence position do not effect in the same percentage to all vowels, so neither the factorial model and nor the additive model can capture these interactions fully. A combination of sums and products more beautifully captures and reflects the properties of duration, as directional invariance and interactions. Several sum-of-products models have been proposed which model either the duration or logarithm of the duration, and all these models give near about the same results. For vowels the best results are obtained by the following sum-of-products model (Bonafonte A. et. al.)

$$D(v,a,c,p,t) = S_{1,1}(v) + S_{2,1}(v,a) + S_{3,1}(v) \, S_{3,2}(p) \, S_{3,3}(c) \, S_{3,4}(t) \tag{14}$$

Here (v) denotes vowel identity, (a) stress, (p) sentence position, (c) class of post vocalic phone and (t) the manner of articulation of post vocalic phone.

For a given number of factors there are many different sum-of-product models. For example for two factors there are five possibilities: $S_{1,1} \times S_{1,2}$, $S_{1,1} \times S_{2,2}$, $S_{1,1} + S_{2,1} \times S_{2,2}$, $S_{1,2} + S_{2,1} \times S_{2,2}$, $S_{1,1} + S_{2,1} \times S_{2,2} + S_{3,2}$. The number of possible models increases rapidly with the number of factors: it is roughly propotional to $2^{2n-1} - 1$, where n is the number of factors.

Many factors are ordered such that their effects are never reversed by other factors but their magnitudes may be modulated by other factors. This property is known as single factor independence and a generalized form of it is known as join factor independence, which means that the order of joint effects of two or more factors stays the same. For example durations of combinations of vowel identities and syllabic stress values (e.g. [/i/ , 0-stressed], [/e/ , 1-stressed]) have the same order in phrase-final and phrase-medial position. But this is not true in all cases for example no such property is exhibited for the combination of vowel identities and postvocalic consonants. [TTS]

There is a direct mathematical link between the ordinal properties of the data set and the sum-of-products model: In the data set when the factors are ordered they exhibit regular patterns of joint independence and amplificatory interactions. The sum-of-products model captures these properties of the segmental duration data. The key assumption made here is that the ordinal structure discovered in the training database can be found in the language in general (restricted to the same speaker and speaking mode). These properties exhibited are the resultant of the stable properties of the speech production apparatus. For example the non-reversal of the syllabic stress factor is linked to the supposition that stressed syllables are pronounced with more sub glottal pressure, increased tension of the vocal chords and larger articulatory excursions than unstressed syllables. The change in timing is a resultant of change in these factors.

An example of the usage of the model based on Catalan TTS is predicting the duration for /a/ (always stressed) in prepausal position followed by /p/ (voiceless plosive). The duration predicted using the values from table 1 is 83.28ms (73.38 + 1.17 * 4.25 * 1.99). From the table the effect of prepausality ($S_{3,2}$) on the vowel lengthening is very noticeable (this effect is accentuated in syllable final position, i.e. followed by silence ($S_{3,4}$)). The contrastive effect of voicing on Catalan vowel duration is also evident from the table. (Febrer, A. et. al.)

v	S1,1	S2,1	S3,1
a	73.38	0.00	1.17
e	41.55	34.79	1.64
i	58.64	16.4	1.80
o	66.38	0.00	1.47
u	59.47	16.59	1.09
E	76.59	0.00	1.61
O	74.70	0.00	1.43

@50.200.001.21

p **S3,2** Prepausal 4.25 Non-prep 1.00

c **S3,3** Voiced 2.41 Voiceless 1.00

t **S3,4** sil 5.84 vow 6.17 nas 1.00 vib 2.23 plo 1.99 app 2.66 fri 3.89 lat 2.05

Table 1: Parameters for sum-of-products for vowels for Catalan

The difference in the nature and properties of different consonants motivates the division of the model for consonants in a set of subsystems based on the manner of articulation. The capability of

extrapolating and generalizing provided by the sum-of-products model proves more effective when the set of descriptor vectors is restricted to similar contexts. Possible subsystems to be analyzed could be the nasals, voiceless plosives, voiced plosives, fricatives and liquids (Bonafonte A. et. al.). A sum-of-products model for consonants and the results for the Catalan language are given in (Febrer, A. et. al.).

Along with the property of interpolation and covering up for the missing data, the duration models also have the noise suppression property, i.e. even when the data are noisy the durations estimated by the model are close to true durations.(Santen .J; 1994)

4.5. Classification and Regression trees (CART)

In CART based modeling the feature space is divided to minimize prediction error and constructs a tree representing the partition of the feature space (Bat°ušek .R). In CART, in the training phase, a tree is formed by successively dichotomizing the factors (e.g., the stress factor is split into 1-stressed, 2-stressed vs. unstressed) to minimize the variance of the durations under the two newly formed subsets of the speech corpus. For each node of the tree, the observed average duration of the associated subset of the speech corpus is listed. In other words, CART is a general purpose statistical method that imposes little structure on the data. In a way, it is a condensed lookup table (Sëayli, Ë; 2002).

Classfication and regression trees (CART) are a statistical modeling technique used to predict a value of a variable y using the corresponding feature vector f. The following example gives a clear idea of the prediction process used by CART trees.

The steps followed to predict the duration of a speech segment f described by the feature vector $f = (phid = t\_S, previd = i, nextid = e,...: , wordpo s = m) are:$

Using the tree shown figure 2 first, we ask the question in the root node: *Is* f *long vowel?* As f is not a long vowel, we continue asking the question in the right descendant of the root node: *Is* f

unvoiced plosive, fricative or affricate? We continue asking questions until a terminal node is reached. A value in the terminal node is the predicted duration (107.7 ms for the sample segment).
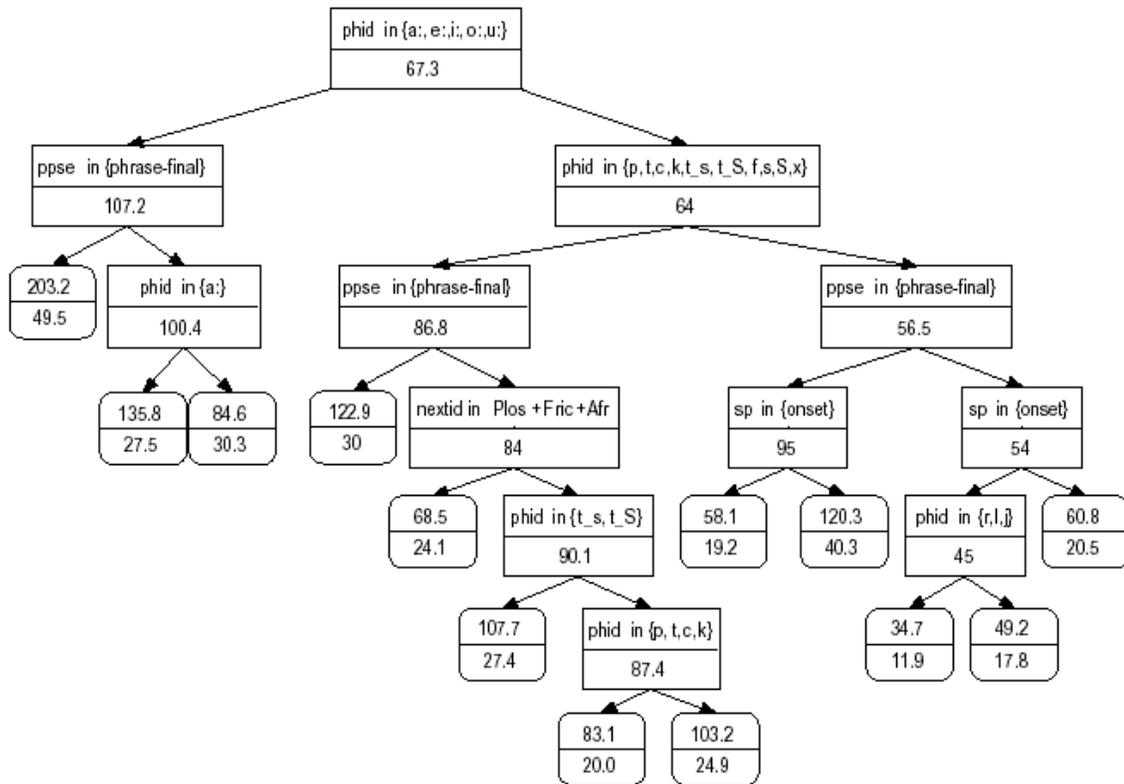
Figure 2: Regression tree for predicting segmental duration for Czech.

The tree construction consists of three steps:

- Building a tree
- Pruning subtrees and
- Selecting an optimal tree.

To build a tree a training (or learning) set L is needed. The training set is in the form { (f^n, y^n) ; n = 1, 2, … , N}where f^n are feature vectors of corresponding objects and y^n values of the dependent variable. Tree construction starts with the tree consisting only of a root node t_1 containing all of the cases in L. The task now is to find the optimal binary split of the data. For real-valued feature i

all splits of the form $f_i^n < \tau$ are tested. For the M-valued categorical feature i, splits have the form $f_i \in \Theta$ where Θ goes through all subsets of the set of all possible values of the feature i. The best split across all features is selected and the data in the root node is splitted and sent into nodes tL; tR. This procedure is applied recursively to all descendants until a stopping condition is ful-filled. Root mean square error is used as a splitting criterion

After the tree construction phase, a relatively large tree Tmax is obtained. Some branches are pruned and a tree sequence Tmax $\supseteq \ldots \supseteq$ Tk $\supseteq \ldots \supseteq$ TK $= t_1$ is constructed. Among these trees the best tree is selected using a test sample independent on a training sample.

The CART-based approach has several advantages. It provides the simplicity of interpretation of the final classifier and the possibility of combination of categorical and realvalued features (Bat°ušek .R). However CART based models have no means of dealing with missing feature vectors other than by pooling whereas the sum-of-products models uses interpolation. If for a given feature vector there is no case defined in the CART tree, the tree has no way to predict it's value and gives an erroneous result, however in case of sum-of-products model interpolation helps get the accurate value. When data possess an ordered structure, CART-based methods cannot make use of that structure (Santen .J; 1994).

4.6. Statistical Methods

As will be discussed in coverage issues analysis of data other than those where a small number of factors is carefully counterbalanced and where the remaining factors are kept constant encounters a serious problem, which is that combinations of factor levels (cells) occur with unequal frequencies, thus causing confounding between factors. In fact data is so sparse that most cells either rarely occur or do not occur at all while a few occur quite frequently, this is called factor confounding (Santen .J; 1992). Due to this factor confounding the durations corresponding to our factor of interest or the critical factor may be affected by other factors (confounding factors). For example in study done to study durations of English, in the data bases analyzed, word final syllables in polysyllabic words were about five times more likely to be unstressed than stressed, while non word final syllables were two times more likely to be stressed. As is well known that

word final syllables have longer durations as compared to word medial or word initial ones, however due to this lopsidedness in data found the word final syllables in the polysyllabic words were shorter in duration. This was due to the polysyllabic factor confounding with the word final lengthening factor. So in this case the raw uncorrected means were actually in reverse order from what they should have been which makes the general case that without more sophisticated analysis raw durations can be completely deceptive. These problems become significantly worse if the data being analyzed has a very small range of textual variations. The techniques used to deal with such situations the Quasi minimal pairs and sets, piecewise multiplicative correction and the sum of products model (already discussed).

4.6.1. Quasi-minimal pairs and sets

Even when all observations (vectors) are not found in the data set, there still may be combinations that occur with all levels of the factor being studied, we may have several observations for

      {unstressed, word final, /u/ }
and
      {stressed, word final, /u/ }
but not for
      {unstressed, word final, /e/ }
      {unstressed, non word final, /e/ }

In these pairs, the conditions are matched on position in word and stress factors repectively. Pairs of conditions such as these are called quasi-minimal-pairs. The difference between the duration means of the two conditions in a quasi minimal pair provides a measure of the effects of the factor being studied since it cannot be attributed to the effects of other factors on which these conditions match (as they behave as constants here). The concept of a quasi-minimal pair can be extended to that of a quasi-minimal set, where a combination of levels on confounding factors occurs with several levels on the critical factor, not necessarily two.

The analysis of quasi-minimal pairs assumes that there exit no quasi-minimal pairs outside the database being observed which have values that are in opposite direction to that being observed inside the database. The belief that no such sets exist rests on the assumption of single factor independence (already discussed in sum of products models) which says that the direction effects of a factor is independent of other factors. Meaning that for a factor, its' effect will always be in the same direction, we won't find cases when in one cases stress effect causes an increase in duration whereas in other it causes a decrease. This assumption is true for many factors.(Santen .J; 1992)

4.6.2. Piecewise multiplicative correction

"When for a given critical factor not enough quasi-minimal pairs or sets can be found, a different method can be used that relies on the assumption that the effect of critical factor and the joint effects of the remaining factors combine multiplicatively. If the the j-th factor is denoted as F_j (where F_j has levels f_j, $f\`_j$, $f\`\`_j$, …), the critical factor as F1, and DUR $(f_1,…,f_n)$ to be "true" duration of the cell defined by F_1 having level f_1, F_2 having level f_2, etc, then piece wise multiplicativity is defined as

$$DUR (f_1,…,f_n) = A(f_1) \times B(f_2,…, f_n)$$

Where A and B represent unknown parameters to be estimated from the data. They reflect the contributions of the critical factor F_1 and the corrective factors F_2, …, F_n respectively ." Here the additive rule (by using the '+' sign) could also be used, but the multiplicative rule generally better fits the duration data than the additive rule.

The word piece wise emphasizes that we are not assuming complete multiplicativity, which would mean that

$$DUR (f_1,…,f_n) = A(f_1) \times B(f_2) \times B(f_3) \times…\times B(f_n)$$

This means that the term $B(f_2,\ldots, f_n)$ need not be itself multiplicative, and may in fact involve arbitrary complex interaction patterns. The strength of the multiplicative combination rule is that it allows estimating the contribution of the critical factor corrected for the effects of confounding factors.

As with the quasi minimal sets method the effects of a factor as estimated with the multiplicative correction method are likely to vary with different selections of corrective factors. Both of these methods have difficulties with factors that have many levels. However in the process of analyzing factors when one discovers which levels on factor make a difference, this knowledge can then be used to reduce the distinctive levels on these factors. For example the post vocalic consonant identity factor can be reduced from the whole space to the classes of consonants based on manner or place. (Santen .J; 1992)

5. Problem Statement

The statement of problem for the thesis work presented is:

"To attain the greatest degree of naturalness in text to speech systems, the values of the prosodic functions like duration and intonation must be accurately predicted. This thesis will attempt to predict the duration of Urdu Vowels and Consonants using the Sum of Products (SOP) model. The SOP is known to predict the values with the greatest accuracy amongst all the models available."

A detailed duration study for Urdu Vowels and Consonants will be conducted. These include:

1. *The Find the default durations of all Vowels and Consonants of Urdu.*

2. *Find the effect of the following factors on the duration of selected Urdu Vowels and Consonants.*

   Factors to be studied for Urdu Vowels:
   - *Stress*
   - *Influence of adjacent Consonants*
     - o *Voicing*
     - o *Aspiration*
   - *Position in Word (final / non final)*
   - *Syllable Type (Open / Close)*
   - *Number of Syllables*

   Factors to be studied for Urdu Consonants:
   - *Stress*
   - *Position in Word (final / non final)*
   - *Position in Syllable (Onset vs. Coda)*
   - *Syllable Type (Open / Close)*
   - *Number of Syllables*

3. *Make the SOP duration prediction model.*

6. Duration modeling for Urdu

This section reports the scope and methodology for the intrinsic duration calculation and the durational study. The section proceeds by reporting few results for a prototypical study done to find durational patterns for Urdu. This prototypical study was done on only one factor (Position in word) to have an idea of the trends exhibited. The complete and detailed results of this thesis are reported in the sections 8 and 9.

6.1. Intrinsic Duration Calculation.

6.1.1. Scope:

Intrinsic durations for the phonemic inventory of Urdu shall be found. These include 16 vowels (7 long vowels, 6 nasalized vowels and 3 short vowels), 13 diphthongs and 37 consonants. These are listed as follows:

Vowels:

Type	Position		Sound
	Front/Back	High/Low	Symbol
Long	Front	High	i
		Middle	e
		Low	æ
	Back	High	u
		High-Middle	o
		Low-Middle	ɔ
		Low	ɑ
Short	Front	High	ɪ
	Back	High	ʊ
	Middle	Middle	ə
Nasalized Long	Front	High	ĩ
		Middle	ẽ
		Low	æ̃
	Back	High	ũ
		High-Middle	õ

| Low | ã | |

Diphthongs: ɪũ, əe, əe, ɑo, ɑi, ɑe, ea, oi, ɑẽ, oe, ə̃ɪ, ɪɑ, ɑũ

Consonants:

m, t, ḍ, d̪ʰ, n, t, k, g, ŋ, q, f, w, s, ʃ, χ, h, dʒ, l, p, pʰ, bʰ   mʰ, t̪ʰ, d, tʰ, d

ʰ,   kʰ, gʰ, z, ɤ, tʃ, tʃʰ, dʒʰ, r, ɾ, j, ʒ

Consonants not being analysed : rʰ, ɾʰ, lʰ, nʰ.

The complete phonemic inventory of Urdu defined in (Manan.S , et. al. 2001), reports 17 vowels and 43 consonants. For this study 16 vowels and 37 consonants were chosen. the vowels and consonants dropped were the ones which are no longer used by the native Urdu speakers. (Manan.S , et. al. 2001) reports the existence of [ɛ] and concludes that there is high degree of chance that [æ] and [ɛ] are allophones of each other. But the decision is left as a controversy, to be examined in greater depth by further studies. Only one word was reported for this vowel. Thus [ɛ] is not included in the study of intrinsic durations.

Sonorant aspirates (rʰ, ɾʰ, lʰ, nʰ) and the glottal stop (ʔ) was removed from the set to be analyzed. The reason for their elimination was their very rare occurrence in Urdu and the fact many Urdu speakers no longer use them (these aspirated phonemes are disappearing from Urdu). (Mazhar S 2001)

6.1.1. Methodology:

The context for finding the intrinsic duration was chosen so as to mitigate the effects of factors which result in a change in duration. Representative words chosen were in the same segmental context.

For vowels the target vowel was in inter-consonantal, stressed position in C**V**CV syllable template. Word medial position was chosen for the target vowel. The preceding and following consonants were voiceless alveolar and velar stops (t, k) (except for two vowels which were in context of voiceless bilabial and dental stop (p,ḓ) respectively). The preceding and following consonants chosen were similar in manner with close places of articulation to diminish the effect of change in duration due to jaw movements.

For consonants the target consonant was in intervocalic unstressed position in the CV**C**VC syllable template. The preceding and following vowels were the long back vowels (u, o, ɔ, ɑ) and short vowel (ɪ,ʊ,ə) respectively in most of the cases. The constraint of having the consonant preceded by short vowel was to have the consonant in unstressed position. Words for consonants were taken from the Urdu lexicon, and wherever possible highly familiar words were selected.

Twenty four (24) repetitions of each word were recorded and analyzed to have generalized duration values. Four repetitions of each word were said by each speaker.

The selected speakers belonged to age group 22-24 and had a Lahori-Urdu accent.   A total of six speakers, three males and three females were chosen. Special care was taken while selecting the speakers to ensure that their speech was clear and that the inter speaker speaking rate was almost the same. The overall speaking rate was in range that was typical for connected speech.

The recording was carried out in a noise free environment. Each speaker was made to speak the selected words within a carrier phrase. The sentences were randomized to ensure the natural delivery of the words, flash cards were used for this purpose. Every sentence was recorded four

times to remove any discrepancies. The equipment for recording consisted of a high fidelity microphone and a Teac integrated stereo amplifier.

6.2. Durational Effects Study

6.2.1. Methodology

A review of the available literature on duration models of different languages was done and the set of factors reported to have significance in duration modeling were chosen. The impact of the following factors was chosen to be studied. The factors chosen are the ones which are reported to have the most significant effect on duration by the literature on duration.

Factors to be studied for Urdu Vowels:
- Stress
- Influence of adjacent Consonants
    - Voicing
    - Aspiration
- Position in Word (final / non final)
- Syllable Type (Open / Close)
- Number of Syllables

Factors to be studied for Urdu Consonants:

- Stress
- Position in Word (final / non final)
- Position in Syllable (Onset vs. Coda)
- Syllable Type (Open / Close)
- Number of Syllables

Word level analysis was chosen for the initial study, future plans include enhancing this analysis to sentence level using standard text and speech corpora. As discussed in the duration analysis part there are various positions where durations are expected to differ, these positions are word

final position, syllable boundary, phrase boundary, sentence ending position, and word initial position. In an analysis done on Telugu language (Girija.P, Sridevi.A), the levels considered for the "position in word" factor are word initial, word medial and word final positions , however in general most of the analysis done for different languages differentiated on the basis of word final, non word final basis only. The same i.e. the study of word final lengthening was chosen as the initial goal for this study.

Having decided the factors to study, for each vowel we had a vector

{Stress, Preceding consonant, Following consonant, Syllable type, Position in word}

and for each consonant a vector,

{Stress, Position in word, Position in syllable, Syllable type, No of Syllables}

with each factor having the levels as:

Stress = {stressed, unstressed}
Preceding consonant = {voiced, unvoiced, voiced aspirated, unvoiced aspirated}
Following consonant = {voiced, unvoiced}
Syllable type = {open, closed}
Position in word = {word final, non word final}
Position in syllable = {onset, coda}
No of Syllables = {1, 2, 3}

In case of "Following consonant" the aspiration effect was not counted as having as any effect since aspiration occurs after the burst of any stop (in general it appears after the phoneme itself) and is assumed to have no effect on the duration of the preceding vowel.

A matrix of these factors was made. As expected there were many repetitions and many cases which were not applicable to Urdu language. For example according to the stress assignment rule

in Urdu (Hussain, S. 1997) , the feature vector {stressed, …, open, word final} can never exist. All such cases were removed by careful analysis based on linguistic knowledge of Urdu. For each vowel and consonant being studied representative words were found. For example in case of the prototypical study on word final lengthening representative words were found with the vowel occurring in word initial and the word final position, having all other factors which effect duration as constant. The words chosen for the prototypical study are shown in Table2.

6.2.2. Selection of Vowels and Consonants

Vowels chosen for this duration study are the four cardinal long vowels /ɑ/, /u/, /i/ and /æ/, the three short vowels /ə/, /ʊ/ and /ɪ/, the nasalized long vowel /ɑ̃/ and the diphthong /ɑẽ/. The idea was to find the trend followed then interpolate them over to the other vowels in the vowel quadrilateral. Thus the vowels chosen are the following:

ɑ	u	i	æ	ɑ̃	ə	ʊ	ɪ	ɑẽ

For the selection of consonants, the objective was to cover almost all the manners of articulation, so for this purpose the place of articulation was fixed at alveolar and all the alveolar sound were chosen. The reason for fixing the place of articulation was also to avoid the effect of factor place of articulation. The manners of articulation chosen are Stops (aspirated and unaspirated), fricatives, affricates, trill, flap and lateral. For the sake of completeness of the study, the two nasals stops /m/ and /n/ were also included. Thus the consonants chosen are the following:

m	n	t	d	tʰ	dʰ	s	z	cʰ	j	r	rɽ	l

6.2.3. Selection of words

The context for finding the words was chosen so as to mitigate the effects of factors which result in a change in duration. In case of vowels, place of articulation for the preceding and following consonant was fixed at alveolar, velar and bilabial. The manner of articulation for all the

consonants was stops, only one manner was chosen so as to avoid the effects of manner of articulation and to have exact results. All words were of two syllables; however no restriction on syllable structure was imposed so as to have a reasonable range of words for the study. In case of consonants words of three syllables were also chosen.

An electronic lexicon was used for the purpose of word finding. Due to the strict context (place and manner of preceding and following consonant) in which to find the words, not all the categories (descriptor vectors) could be filled in. Also certain categories had words for some vowels but not all. For example for the diphthong /ɑẽ/ only words of template كها ئىں، دكهائىں were found, which was obviously owing to the fact that the Urdu language did not had much words in which diphthong /ɑẽ/ existed in any context other than word final. For example this word doesn't conform to the context decided for the prototypical study, also no pair was found relevant to study the "position in word" factor.

6.2.4. Selection of speakers

For the acoustic analysis the selected words were recorded as spoken by different speakers. The selected speakers belonged to age group 22-24 and had a Lahori-Urdu accent. A total of six speakers, three males and three females were chosen. Special care was taken while selecting the speakers to ensure that their speech was clear and that the inter speaker speaking rate was almost the same. The overall speaking rate was in range that was typical for connected speech.

6.2.5. Recordings

The recording was carried out in a noise free environment. Each speaker was made to speak the selected words within a carrier phrase. There are two types of speech corpus. In one carefully designed sentences are recorded to minimize the effects of factor confounding. However this does not capture actual durations as the sentences or the words are recorded in a carrier sentence and the repetitive use of the carrier sentence may undermine how naturally the text is read. The other

approach is to use naturally occurring meaningful sentences. This has the advantage of a more natural reading style but the disadvantage of creating confounding. The later approach was used for this study.

The sentences were randomized to ensure the natural delivery of the words, flash cards were used for this purpose. Every sentence was recorded four times to remove any discrepancies. The equipment for recording consisted of a high fidelity microphone and a Teac integrated stereo amplifier.

Twenty four (24) repetitions of each word were recorded and analyzed to have generalized duration values. Four repetitions of each word were said by each speaker.

6.2.6. Duration finding

Analysis of the speech was carried out using Praat 4.2. and spectrograms were read to study the duration of the vowels. The analysis was done by 1 graduate and 2 undergraduate students. All were well equipped with spectrogram reading knowledge and had been in active dealing with spectrogram reading for almost 8 months (Reading and splitting spectrograms for speech synthesis applications). In general the vowel onset was measured from the first peak or trough at which the formant characteristics of the vowel became visible. A variation of one to two peaks (approximately 10 ms) was catered for. Vowel offset was determined similarly. In case of aspiration of the preceding consonant, the aspiration part was not included in the vowel duration.

6.2.7. Analyzing Durations

Even when all observations (vectors) are not found in the data set, there still may be combinations that occur with all levels of the factor being studied, we may have several observations for

   {unstressed, word final, /u/ }
 and
   {stressed, word final, /u/ }

but not for

> {unstressed, word final, /e/ }

> {unstressed, non word final, /e/ }

In these pairs, the conditions are matched on position in word and stress factors respectively. Pairs of conditions such as these are called quasi-minimal-pairs (Santen .J; 1994).The difference between the duration means of the two conditions in a quasi minimal pair provides a measure of the effects of the factor being studied since it cannot be attributed to the effects of other factors on which these conditions match (as they behave as constants here). The quasi minimal pairs for the prototypical study are given in Table 2. Percentage difference between these pairs gives us the change in duration exhibited in these contexts.

Table 2: Quasi minimal pairs of words

Condition	Word
{stressed, unvoiced, unvoiced, closed, non word final, /u/ }	کوٹنا
{stressed, unvoiced, unvoiced, closed, word final, /u/ }	کرتوت
{stressed, unvoiced, unvoiced, closed, non word final, /ɑ/ }	کاٹنا
{stressed, unvoiced, unvoiced, closed, word final, /ɑ/ }	لوکاٹ
{stressed, unvoiced, unvoiced, closed, non word final, /ə/ }	تِکڑاا
{stressed, unvoiced, unvoiced, closed, word final, /ə/ }	پھدک
{stressed, voiced, unvoiced aspirated, closed, non word final, /ɪ/ }	بِھیر
{stressed, voiced, unvoiced, closed, non word final, /ɪ/ }	ثابت
{stressed, voiced, unvoiced, closed, non word final, /ʊ/ }	دُکان

{stressed, unvoiced, unvoiced, closed, word final, /ʊ/ }	چابک

The words selected and recorded were used to build a duration model using the Festival speech synthesis system. The Festival TTS system was developed in CSTR at the University of Edinburgh by Alan Black and Paul Taylor and in co-operation with CHATR, Japan. Festival is multi-lingual system. Currently English, British, American, Spanish and Welsh are being used though English is the most advanced. As a University program the system is available free for educational, research, and individual use. Festival provides a number of different duration prediction modules with varying levels of sophistication. The duration prediction methods that festival provides are default durations, average durations, Klatt durations, and CART durations.

For this prototypical study a CART duration tree was built using the wagon utility provided by the system. Incorporation of the duration model improved the quality of synthesized sound produced by the system. The sound produced by using the trained duration model sounded more natural than that produced without using the duration model. The results for word final lengthening case using the synthesized sounds produced by using our duration model are shown in Table 4.

6.2.8. Results for the prototypical study

All the vowels exhibited a significant increase in duration when they occurred in word final position. Individual durations for each vowel in the context and the average increase are shown in Table 3.

The results of synthesized sounds produced by the festival speech synthesis system are shown in Table 3. Word final lengthening is obvious, however the percentage increase (40.89%) is greater than in the case of recorded words (34.83%).

Table 3: Durations and percentage change in duration of vowels using recordings

Target Vowel	Context	Duration	% Increase
u	Non word final	102.97	34.60
	Word final	138.59	
ɑ	Non word final	129.04	32.59
	Word final	171.09	
ə	Non word final	49.05	59.94
	Word final	78.44	
ɪ	Non word final	49.20	28.78
	Word final	63.36	
ʊ	Non word final	47.66	18.23
	Word final	56.35	

Table 4: Durations and percentage change in duration of vowels using duration model

Target Vowel	Context	Duration	% Increase
u	Non word final	126.36	38.33
	Word final	174.8	
ɑ	Non word final	137.32	60.74
	Word final	220.73	
ə	Non word final	71.31	43.46
	Word final	102.3	
ɪ	Non word final	62.43	42.58
	Word final	89.01	
ʊ	Non word final	57.97	19.35
	Word final	69.19	

6.2.9. Discussion

All the vowels exhibited an increase in duration when they occurred at the word final position. The general trend followed was that /ə/ showed the greatest increase in duration, i.e. 59.94%, followed by /u/ (34.60%), /ɑ/ (32.59%), /ɪ/ (28.78%) and /ʊ/ (11.71%).These results are shown in Table 2.

The quasi minimal pairs found for the word final case were for the two long vowels /A/ and /ʊ/ and the three short vowels /ə/ /ɪ/ /ʊ/, which represent almost 63% of the data set to be analyzed. 24 repetitions of each word were used (4 repetitions by each speaker). The trends exhibited by the analysis were that the long vowels exhibited an average increase of 33.60% in duration whereas the short vowels exhibited an average increase of 35.65% when they occurred in word final position with respect to non word final position. The general trend exhibited was /ə/ > / u / > / ɑ / > / ɪ / > /ʊ/.

The synthesized sounds produced after implementing the duration model in Festival also exhibited significant lengthening when the vowel occurred at the word boundary (word final).The trend followed in duration change by the synthesized sounds was however different with / ɑ / exhibiting the most change (60.74%) . The general trend exhibited was /ɑ/ > /ə/ > /ɪ/ > /u/ > /ʊ/.

Separate analysis of recordings by male and female speakers revealed that female speakers tend to articulate the vowels more carefully than the male speakers. The average difference of 13% was observed in the duration of recordings of male vs. female speakers. The general trend of duration increase among male vs. female was not the same as that of the combined data. However /ə/ showed the most increase in all cases along with /ɑ/ which is third in number with reference to duration change

7. Results and Discussion: Intrinsic Duration Calculation.

It has long been noticed that the durations of vowels and consonants vary according to the contexts and a great deal of studies have been performed to find these factors and their percentage affect on the phone durations. (House AS 1953)(Umeda N 1960) (Thomas, Arthur; 1987).

Some studies to find the durational effects of different factors employed the use of the default durations. The method used was that of finding the standard deviation from the mean or average durations (Thomas, Arthur 1987). However an analysis of such a sort can be applied only when the affect of only factor is under investigation, so in a sense the mean or average or intrinsic duration value acts as a part of quasi minimal pair with the other part being provided by the other value (i.e. the factor under investigation).

For the completeness of this study, a study for the mean or intrinsic duration of vowels and consonants was done. The scope and the methodology used to find the intrinsic durations has been already explained in section 7.1, this section reports the results found. The final values of the default durations for the phones for each speaker have been reported in Appendix A.

7.1. Vowels:

A study for the default or intrinsic duration for all the 16 vowels of Urdu was done. These included 7 long vowels, 6 nasalized vowels and 3 short vowels.

7.1.2. Long Vowels:

The results obtained for the study of default durations of the 7 long vowels of Urdu are shown in Table 5.

Table 5: Intrinsic durations for the Urdu long vowels in descending order

Long Vowels in descending duration order		
Vowel	**Target word**	**Duration (ms)**
ɔ	پودا	132,92
æ	پیدا	132,27
u	کوٹا	126,57
ɑ	ٹاکی	125,44
e	ٹیکا	114,87
i	ٹیکا	111,58
o	ٹوکا	109,36

The average duration for the long vowels was found to be 121.85 ms. The longest vowel was found to be /ɔ/, having duration of 132.92 ms and very close to it was the long vowel /æ/. The vowel with the minimum length was found to be /o/, having duration of 109.36ms. The difference between the longest and the shortest long vowel was found to be 23.60 ms .These trends are obvious in the Figure 3.
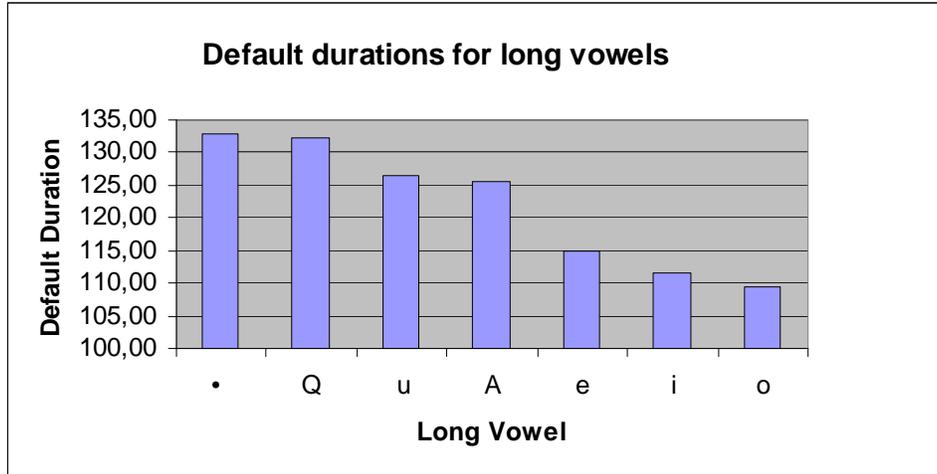
Figure 3: Intrinsic durations for the Urdu long vowels in descending order

7.1.3. Nasalized Vowels:

Urdu language has 6 nasal vowels, which are basically the corresponding nasal versions of six of the long vowels, with the exception of the long vowel /ɔ/. The results for the study of default durations for the nasal vowels are shown in Table 6.

Table 6: Intrinsic durations for the Urdu nasal vowels in descending order

Nasalized Vowels in desceding durations		
Vowel	**Target word**	**Duration (ms)**
ĩ	لیں	233,45
õ	ہوں	226,30
ũ	لوں	214,50
ẽ	میں	202,19

ã	ماں	196,23
æ̃	میں	193,09

The average duration for the nasal vowels was found to be 210.95ms. The average percentage difference in duration of the long vowel and the corresponding nasal vowel was found to 46.02 %. The individual trend for each vowel is shown in the Figure 4.
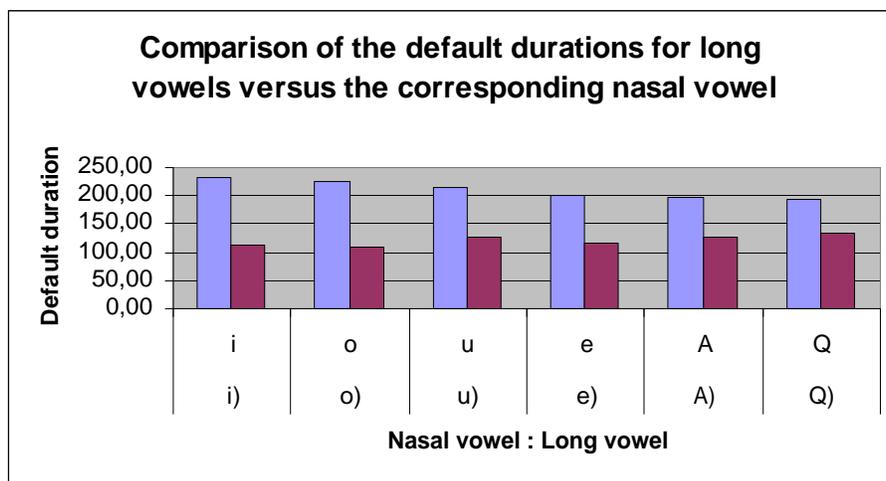
Figure 4: Default durations, Nasal vowel versus corresponding long vowel

7.1.4. Short Vowels:

The intrinsic duration values found for the short vowels have been reported in the Table 7.

Table 7: Intrinsic durations for the Urdu short vowels in descending order

Short Vowels in desceding durations		
Vowel	**Target word**	**Duration (ms)**
ʊ	گُک	70,39
ə	گَٹ	69,59
ɪ	گِک	56,59

The average default duration for the short vowels was found to be 65.52 ms. The longest short vowel was found to be /ʊ/ having an intrinsic duration of 70.39ms and the shortest was /ɪ/ having an intrinsic duration of 56.59ms. The difference between the two being 13.79ms. The trend of the durations found is shown in Figure 5.
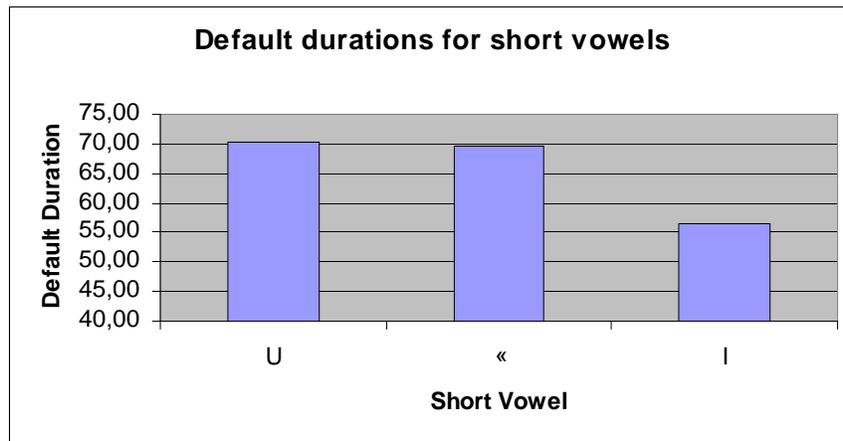
Figure 5: Intrinsic durations for the Urdu short vowels in descending order

7.1.5. Diphthongs:

The study of default durations for Urdu diphthongs was also a part of the study. Numerous studies have been done to find the exact number of diphthongs for Urdu. (Sarwar et. al. 2003) and (Khurshid et. al. 2003) report a detailed analysis done on the Urdu diphthongs, the later goes on to discuss the existence of trip thongs in Urdu too. For the purpose of the study of default durations 13 diphthongs were chosen, which were actually an intersection of the diphthongs found by the two studies. The default values obtained by this study are reported in Table 8 and the trend is shown in Figure 6.

Table 8: Intrinsic durations for the Urdu diphthongs in descending order

Word	Diphthong	Duration (ms)		Word	Diphthong	Duration (ms)
کیا	ɪɑ	277,01		کیوں	ɪũ	232,22
کھائیں	ɑẽ	262,96		کئی	əi	227,67
تاؤ	ɑo	250,12		گئے	əe	227,10
گیا	eɑ	248,05		کوء	oi	218,08
تاء	ɑi	245,18		کھوئے	oe	214,22
تائے	ɑe	242,27		کھاؤں	ɑũ	189,88
گئیں	əĩ	238,69				
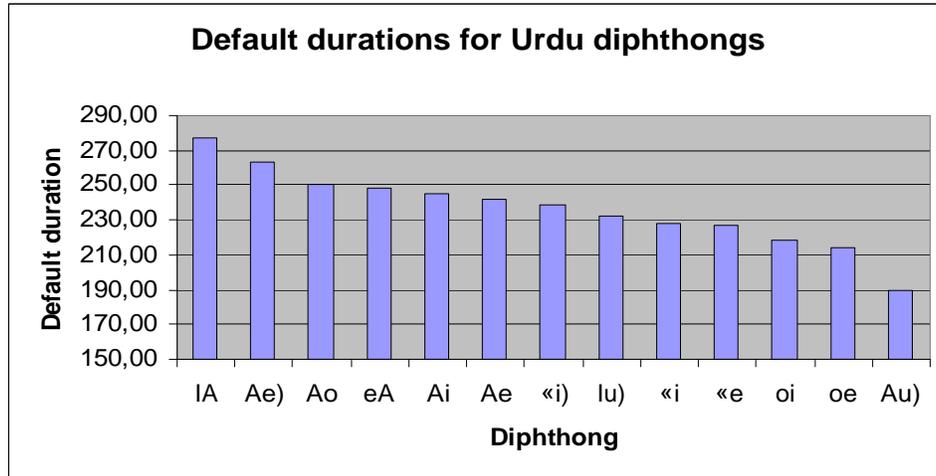
Figure 6: Intrinsic durations for the Urdu diphthongs in descending order

The longest diphthong of Urdu was found to be / ɪɑ / with default duration of 277.01ms; and the smallest diphthong of Urdu was found to be / ɑʊ̃ / having a default duration of 189.88ms. The average default duration for the diphthongs of Urdu was found to be 236.42ms with a standard deviation of 22.29ms.

An additional study shown in Appendix B was done. The intuition behind this was based on the concept that a diphthong is a combination of vowels. The study was done to determine whether the duration of the diphthong is longer or less than the combined duration of the composing vowels. The results obtained showed a mixed trend. The idea was that perhaps this method may be used to determine whether it is a diphthong of the language or just two vowels coming together. In my personal opinion, the cases where the sum of the two composing vowels was less than the duration of the diphthong, it did seem like two syllables and not one diphthong to me, but this is highly personalized. A detailed study needs to be done on this, which however, definitely is out of the scope of this study. A study of such sort has been done in (Khurshid et. al. 2003).

7.2. Consonants:

In Urdu there are a total of 43 consonants (Manan.S , et. al. 2001), 37 of which were chosen for this study. For a discussion on the scope of this study, refer to section 7.1.1. The context for word finding for consonants was different as that for vowels and is defined in section 7.1.1.

This section reports the results found for Urdu consonants. The results will be presented in accordance with the manner of articulation, as it allows for a better analysis. Table 9 reports the results obtained for Urdu stops.

Table 9: Intrinsic durations for the stops in Urdu

Intrinsic Durations for Stops in Urdu						
Voiced				Unvoiced		
Consonant	Word	Duration (ms)		Consonant	Word	Duration (ms)
b	صابر	90,97		p	چاپڑ	126,24
ḍ	چادر	89,70		ṭ	قاتل	109,57
d	میڈم	63,85		t	نائٹ	104,93
g	ساگر	86,78		k	نوکر	119,88
bʰ	دوبھر	90,50		pʰ	داپھڑ	135,50
ḍʰ	سادھن	88,50		ṭʰ	گاٹھک	126,63
dʰ	چوڈھل	82,05		tʰ	بیٹھک	98,07
gʰ	جیگھڑ	93,34		kʰ	چوکھٹ	121,58
q	عاقل	126,79				

؟	ساعت	102,18				

An obvious observation was that the unvoiced stops were longer in duration than the voiced stops. This observation has been shown in Figure 7. The average difference in duration was 38.24 %. For unaspirated stops this difference was 40.84% whereas for aspirated stops was 35.64%. For the sake of completeness of the study the velar stop /q/ was also included in the study, although it is mostly mapped onto /k/ by native Urdu speakers (Nawaz S 2001). According to (Shahid R 2001), the glottal stop is completely removed from the phonetics of Urdu when it occurs at the location other than at the start of the word or at the start of the first syllable of the word. The existence of the glottal stop /ʔ/ has been reported as a vowel in the other cases. Because of it's existence in special cases, the glottal stop /ʔ/ was included in this study and the results are shown in Table 9.
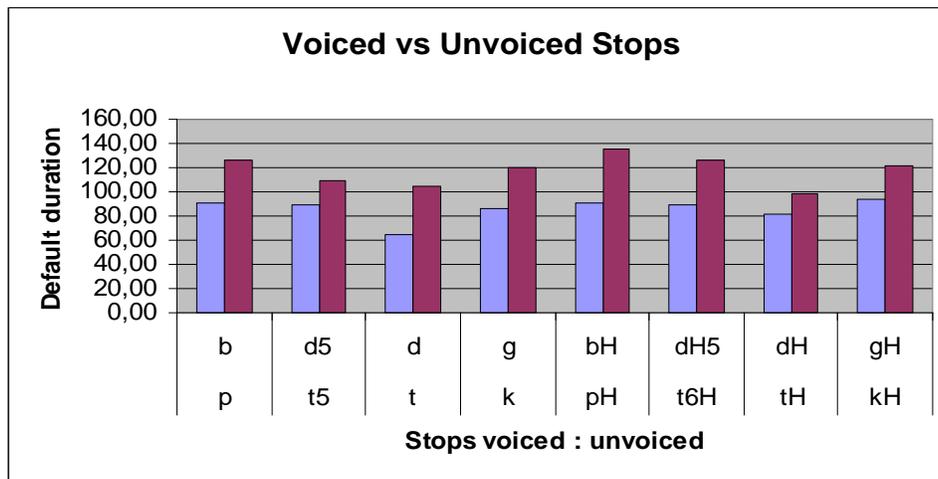
Figure 7: Intrinsic durations, voiced stops versus unvoiced stops

The average duration for voiced stops was found to be 85.71 ms with a standard deviation of 9.44ms. /q/ and /ʔ/ have not been included in average and standard deviation calculation. In the case of unvoiced stops, the average duration was found to be 117.80 ms with a standard deviation of 12.55ms.

Table 10: Intrinsic durations for nasals of Urdu

Nasals						
Consonant	**Word**	**Duration (ms)**		**Consonant**	**Word**	**Duration (ms)**
m	جامن	79,35		m^h	جیمھر	127,54
n	دانش	66,39		n^h	دمنھا	146,50
				ŋ	آنگن	116,39

The results obtained for the nasals of Urdu are shown in Table 10. The results for voiced velar nasal /ŋ/ have been reported along with the nasals. The average default duration for the nasals was found to be 72.87 ms and that for aspirated nasals was found to be 137.01ms. On average the default duration of the bilabial nasal /m/ was found to be 16% longer than that of the dental nasal /n/. The same trend in difference of duration, based on the place of articulation, was observed in the duration of stops, see Table 9 but there the difference was a minor one. The average percentage difference between the duration of nasals and aspirated nasals was found to be 37.01%.

The Table 11 reports the results of this study for the fricatives of Urdu. The average duration for the voiced fricatives was found to be 75.54ms, whereas that for unvoiced fricatives was found to be 111.60ms. As in the case of consonants, the durations for unvoiced fricatives were found to longer than those of voiced fricatives and the percentage difference was 49.55 %. This trend is shown in Figure 8.

Table 11: Intrinsic durations for the stops in Urdu

Fricatives				Fricatives		
Voiced				**Unvoiced**		
Consonant	Word	Duration (ms)		Consonant	Word	Duration (ms)
w	کاوش	63,19		f	کافر	114,30
z	لازم	76,32		s	موسم	111,64
ʒ	ژالہ باری	82,11		ʃ	ہاشم	110,68
ɤ	ساغر	80,56		χ	داخل	109,75
h	ساحل	76,43				
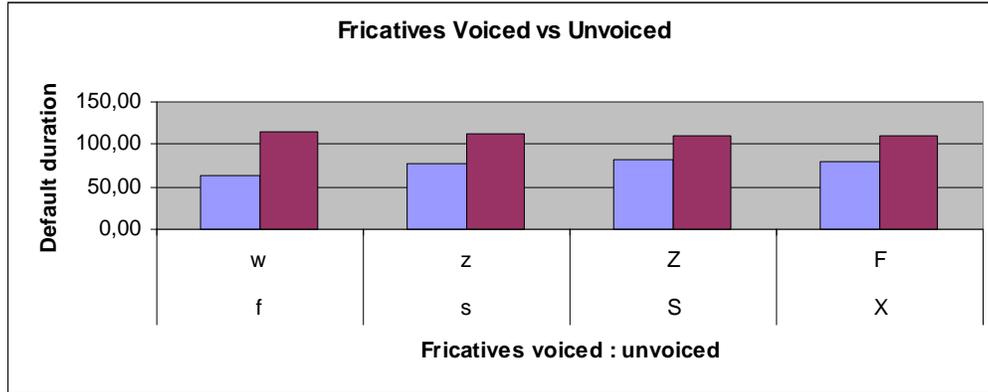
Figure 8: Intrinsic durations, Voiced fricatives versus Unvoiced fricatives

The same trend of unvoiced sounds being longer than voiced sounds was observed in the study of default durations for affricates. The difference found being 20.33 ms for un-aspirated affricates and 31.66ms for aspirated affricates. On average, the average default duration for voiced affricates was 101.74 ms and that for unvoiced affricates was found to be 114.48 ms. The average difference

in duration of voiced versus unvoiced affricates was found to be 21.25%. The results are reported in Table 12.

Table 12 : Intrinsic durations, Voiced affricates versus Unvoiced affricates

Affricates							
Voiced				Unvoiced			
Consonant	Word	Duration (ms)		Consonant	Word	Duration (ms)	
dʒ	کابل	91,58		tʃ	ماچس	111,91	
dʒʰ	اوجھل	98,65		tʃʰ	باچھل	130,32	

The results for the trill /r/, flap /ɾ/, lateral /l/ with their aspirated versions and that for the approximant /j/ are given in Table 13. The words found for the aspirated versions are rarely used and most of the speakers of Urdu are not even aware of these words, the reason being the rare use of these aspirated approximants in Urdu as has been reported by (Mazhar S 2001).

Table 13: Intrinsic durations, Approximants

Approximants						
Consonant	Word	Duration (ms)		Consonant	Word	Duration (ms)
r	چورس	22,80		rʰ	دھارہی	40,15
ɾ	گوڑل	32,84		ɾʰ	کوڑہن	31,98
l	مالک	70,65		lʰ	پیلھڑ	89,53
j	یاد	80,21				

8. Results and Discussion: Durational Effects Study

It was observed that the holes in data (in context to the quasi minimal pairs analysis) for vowels were approximately three times for vowels as for consonants. As already defined in the literature review hole in the data corresponds to the unavailability of data. Also the word finding process for vowels was more time taking as there were not sufficient words available. The reason for this scarcity of words was the strict conditions for word finding for the analysis. For example to study the effect of stress, the minimal pair is supposed to have the position in word (word final / initial), position in syllable (open/close), and the aspiration and voicing for the preceding and following consonant as constant i.e, the same and only the stress had to be different (stressed/unstressed) . The strictness of the condition was further aggravated by the factor of voicing and aspiration for the preceding and the following consonant, as on its expansion it increased the cases to 8, 4 of which were however ignored in the analysis. The cases ignored were when the preceding and the following consonant had the same value as in the following cases,

V V
UV UV
aspV aspV
aspUV aspUV

Where V stands for voiced, UV for unvoiced and asp for aspirated.

Although an analysis for the missing cases could have been done by having a comparison with the intrinsic duration values but it would not have been very accurate as the intrinsic duration were found for vowels in specific context (refer the methodology for intrinsic duration calculation section 7.1.1) . However such a rough analysis is done in some cases just to have an idea of the trend. Whenever done, such analysis with intrinsic durations is explicitly mentioned. The results reported in the tables are however the ones obtained with the quasi minimal pairs analysis.

As is obvious and expected no minimal pair was found for the nasal long vowel /ɑ̃/ and the diphthong /ɑẽ/. For a look at the discussion over this refer to section 7.2.3. For an in-depth look at the trends exhibited by the individual vowels and consonants, the quasi minimal pairs have been given in the appendix. A study of these gives an idea as to why such a behavior was exhibited by the phone (as the words have been reported also) and also one gets an idea of the size of data available for the particular case under study.

8.1. Vowels:

8.1.1. Position in word:

Position in word in the case of vowels is defined as the position of the syllable containing the vowel in the word. For the purpose of this study, since the word length for vowels in restricted to 2 syllables (As defined in the scope), the only possible positions are word initial and word final. These two positions however suffice to show the trend of the famous word final lengthening.

The factor of position in word was found to be the most prominent among the entire factor set studied for the vowels. A vowel, if present at the word final boundary, i.e. in the last syllable of the word, has a length 28.83% longer than if it was present in word initial boundary. The large value of percentage suggests almost the same results even if the number of syllables were greater than two. However the exact figure needs to be studied.

Table 14: Percentage increase in the duration of vowels in closed syllables

Net % increase in vowel length at word final position (Position in word)							28.83	
ɑ	u	i	æ	ɑ̃	ə	ʊ	ɪ	ɑẽ
14,97	34,60	-	-	-	49,78	14,97	28,78	-

The Table 14 shows the results obtained, the percentage increase for each vowel is shown graphically in Figure 9.
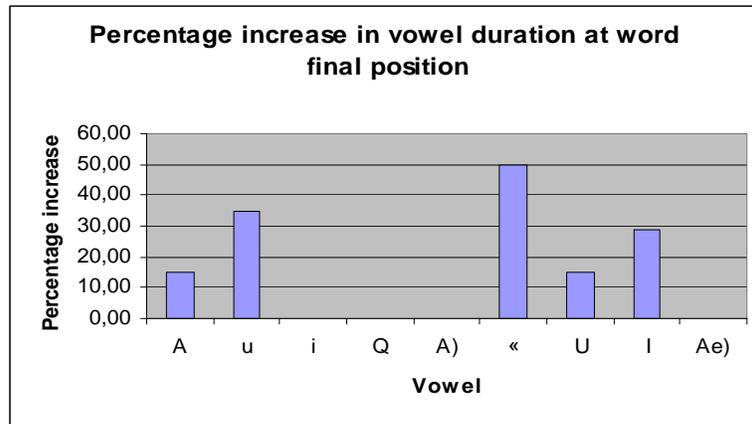
Figure 9: Percentage increase in the duration of vowels in closed syllables

The individual results obtained show a great variability, however not a single result indicates a deviation from the general result. The average increase for long vowels was found to be 24.76 % and that for short vowels was 31.17%. The greatest increase in duration at the word final position is shown by the short vowel /ə/ which almost 50 %. It can be said that it elongates to become /ɑ/, the longer version of /ə/. This phenomenon of a short vowel lengthening to produce the corresponding long vowel is very common and is exhibited by many languages. However this needs to be verified by having a look at the spectrograms which however is out of the scope of this study. The percentage increase for the short vowel /ɪ/ can also be attributed the same reason, the corresponding long vowel being /i/, but the case of the short vowel /ʊ/ defies this explanation, for which also a corresponding long vowel /u/ exists. Interestingly it is the long vowel /u/ which has exhibited the greatest increase in duration among the long vowels.

8.1.2. Effect of Stress:

Syllabic stress has notably known to produce longer durations. According to the study on segmental durations in Institute of Defense Analysis, New Jersey (Thomas, Arthur 1987), it has been reported that for English stressed vowel is 30 ms greater, while unstressed vowels have an average of about 40 ms less.

The results obtained for the percentage effect of stress on Urdu vowels have been reported in the Table 15 and the trends exhibited shown graphically in the Figure 10.

Table 15: Percentage increase in the duration of vowels in a stressed syllable

Net % increase in vowel length in a stressed syllable							8.90	
ɑ	u	i	æ	ã	ə	ʊ	ɪ	ɑẽ
9,01	-	8,06	-	-	14,71	-3,13	5,54	-
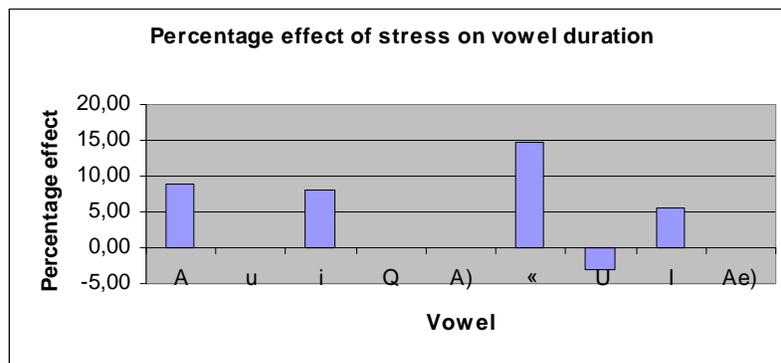
Figure 10: Percentage increase in the duration of vowels in a stressed syllable

The results of this study for the effect of stress on vowel duration showed the same trend, i.e. an increase in vowel duration in stressed condition. The average percentage increase in vowel duration under stressed condition was found to be 8.9 %. For long vowels, the increase in duration was 8.5%, while for short vowels this increase was found to be 5.7 %. The maximum increase was exhibited by the short vowel /ə/. No data was available for the long back high vowel /u/ and the

long front low vowel /æ/, the reason being the strict conditions chosen for the analysis as has already been discussed.

8.1.3. Effect of voicing:

Peterson and Lehiste (1960) found a tendency for vowels preceded by fricatives to have somewhat shorter durations than vowels preceded by other consonants. For pre-vocalic voiceless stops, the interpretation depends on whether to include the aspiration in the vowel or in the consonant. If included in the vowel, this would have made vowel durations longer after the voiceless stops than after the consonants. If included in the consonant, voiced stops would have produced the longest vowel durations. Fischer-Joergensen (1964) also found longer duration for vowels after voiced stops than for vowels after voiceless stops. Crystal and House (1988) also found, in addition, that both voiceless stops and voiced stops produce longer vowel durations than any other consonants, including fricatives. (Santen 1992).

This section investigates the effect of voicing, preceding and following consonant and the effect of aspiration (preceding consonant only) for Urdu. As already stated in section 7.2.1, in case of "Following consonant" the aspiration effect was not counted as having as any effect since aspiration occurs after the burst of a stop (in general it appears after the phoneme itself) and is assumed to have no effect on the duration of the preceding vowel.

As already stated/defined in section 7.2.3, the place and manner of the consonants (following and preceding) were fixed at alveolar, velar and bilabial stops. So the effects reported in the following sections are basically due to the stops only.

8.1.3.1. Effect of voicing (post-vocalic consonant):

There is unambiguous evidence in the literature that the post-vocalic consonant has effects on vowel duration. These effects are usually characterised in terms of voicing characteristics, but

there are also indications that they might include manner of production and place of articulation. (Peterson and Lehiste, 1960; Crystal and House 1988) (Santen 1992).

Table 16: Percentage increase in the duration of vowels when followed by a voiced consonant

Net % increase in vowel length by a following voiced consonant (Post-vocalic consonant)							17.73	
ɑ	u	i	æ	ɑ̃	ə	ʊ	ɪ	ɑẽ
10,43	10,75	24,99	-	-10,91	43,68	-10,25	-	-

The net effect on vowel duration of a post-vocalic voiced consonant versus a post-vocalic unvoiced consonant is 17.73 %. Thus this factor, after the factor "position in word" (initial / final), appears to be the second most prominent factor for vowel duration. This agrees with the pattern studied for other languages, for example English. The effect of voicing of the post-vocalic consonant on the duration of the long vowels was found to be 15.39% and that on short vowels was 7.51%. Interestingly like in the case of word final lengthening (position in word), the highest change in duration is shown by the short vowel /ə/ which is 43.68 % and is close to the 50% in the case of word final lengthening. The same explanation as was given in the later case can be deduced by this large change in duration, but in this case the other short vowel /ʊ/ deviates from this trend. An interesting point to be noted here is that in case of word final lengthening (position in word) it was also /ʊ/ which defied the trend exhibited by the other short vowels. These results are shown graphically in Figure 11.
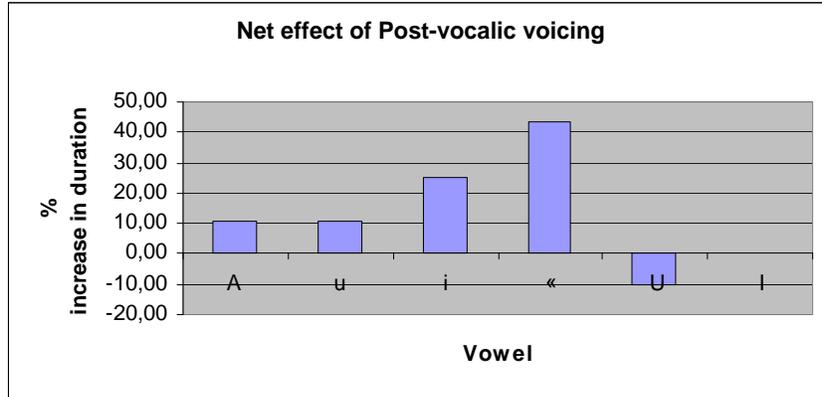
Figure 11: Percentage increase in the duration of vowels when followed by a voiced consonant

An interesting thing to note in the results for this factor is that we have a result for the nasal vowel /ã/ also. It is negative as is obvious from Table 16. This is the correct time for a discussion the results for the nasal vowel /ã/, having a look at the quasi minimal pairs for /ã/ (Appendix E), we find only one pair as follows:

Table 17: The single quasi minimal pair for the nasal vowel /A)/

Vowel	Word	Minimal pairs				Duration in context	Difference	Percentage increase
ã	ٹانگ	stress	open	UV UV	non wf	142,63	-15,57	-10,91
	کانٹ	stress	open	UV V	non wf	127,06		

As can be noted in both the words, the nasalization is a result of the following nasal phoneme /n/, and will be the case every time a nasal vowel will be studied as the nasalization of the vowel is the result of nasal phoneme. So it is not wrong to say that in this particular case, the study of duration of vowel is not valid as the study will actually be the effect of the nasal phoneme, not in general of the post vocalic voiced consonants, as no such words exists in Urdu for analysis.

The result was keep to be presented to give an idea of the cases that turn out in analysis, however it is not plotted in the Figure 11. This particular problem was spotted out during the word finding phase but was kept to be reported, so as to give a clearer picture of cases that were dealt with.

8.1.3.2. Effect of voicing (preceding consonant):

The results obtained by this study found the effect of the preceding consonant to be the third most prominent factor in vowel duration. This factor is the only factor for which the results for the maximum number of vowels are available with the exception of the back long vowel /æ/ and of course the diphthong /ɑẽ/. Also interestingly not a single vowel deviates from the trend. The results for the study are shown in Table 18 and the Figure 12.

Table 18: Percentage increase in the duration of vowels when preceded by a voiced consonant

Net % increase in vowel length by a preceding voiced consonant (Pre-vocalic consonant)							13.89	
ɑ	u	i	æ	ɑ̃	ə	ʊ	ɪ	ɑẽ
7.35	7.53	22.47	-	8.27	30.55	5.71	7.72	-
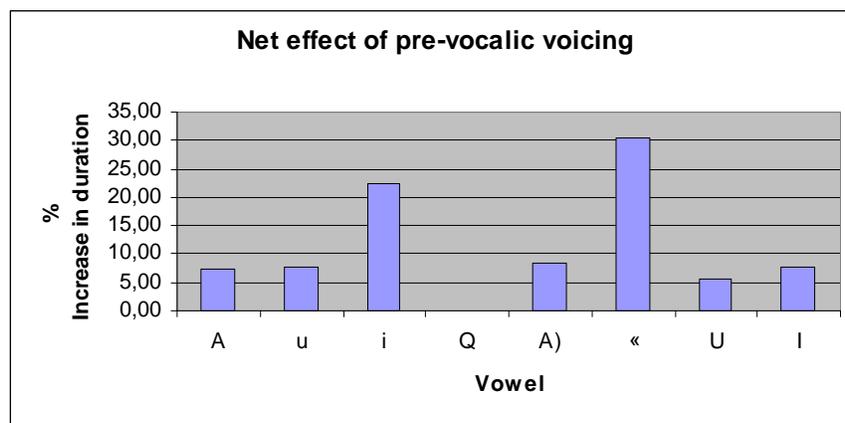
Figure 12: Percentage increase in the duration of vowels when preceded by a voiced consonant

The average increase in vowel length when preceded by a voiced consonant (stop) is 13.89 %. The average increase for long vowels was found to 12.45 % and 14.66 % for short vowels. As observed in all the preceding cases of vowel analysis, the highest change is observed in the duration of the small vowel /ə/ amounting to 30.55 %. The other short vowels exhibit a small change compared to that of /ə/. Among the long vowels, the highest change is exhibited by the long front high vowel /i/, the other long vowels, /ɑ/ and /u/ exhibit an almost equal change in duration. The effect on the nasal front back low vowel /ɑ̃/ was found to be 8.27%.

8.1.4. Effect of aspiration:

Although aspiration has been a topic of keen research and has been studied from many aspects, my search could not find any documented results for the effect of aspiration on duration. Might be there has been work done on it and I missed it as my sole medium of search was the internet.

8.1.4.1. Effect of aspiration (voiced consonant):

The result obtained indicates a 1.1% increase in vowel duration if preceded by a voiced aspirated consonant. This is a bit strange result as one would expect a greater effect after having known that effect of voiced pre-vocalic consonant is 13.89 %. Also as mentioned earlier no reference from literature about the effect of aspiration was found.

Table 19: Percentage increase in the duration of vowels when preceded by a voiced aspirated consonant

Net % increase in vowel length by a preceding aspirated voiced consonant							1.11	
ɑ	u	i	æ	ɑ̃	ə	ʊ	ɪ	ɑẽ
12,72	-	-	-	-	0.27	-9.65	-	-

The reason for such a strange result is the scarcity of data. The result reported above in the table is not an average of values, rather each of the three values reported come each from a single quasi minimal pair for each vowel. Obviously one data set cannot be called a representative of the trend shown by all vowels. The quasi minimal pairs are given is the Appendix 9.4.1.1.

8.1.4.2. Effect of aspiration (unvoiced consonant):

According to the results obtained (reported in Table 20) the effect of aspiration of a preceding unvoiced vowel is 12.85%. The average effect on long vowels is negative, i.e. -12.11 % but for the short vowels is pretty prominent and is 29.49%. Also the longest change of 57.14% is exhibited by the short vowel /ɪ/. Considering these results one can say that aspiration of an unvoiced consonant has a considerable effect on the duration of short vowels. But again a look at the quasi minimal pairs reveals that apart from the short vowel /ə/ all the other vowels had one quasi minimal pair each, which is again not a representative of a general trend.

Table 20: Percentage increase in the duration of vowels when preceded by a voiced aspirated consonant

Net % increase in vowel length by a preceding aspirated unvoiced consonant							12.85	
ɑ	u	i	æ	ɑ̃	ə	ʊ	ɪ	ɑɛ̃
-12,61	-11,62	-	-	-	18.58	12.76	57.14	-

The results obtained gave a strange trend which is basically due to the scarcity of quasi minimal pairs for the aspirated consonants. If considered only the results of voiced aspirated consonants, one feels a tendency to say that aspiration has a very small effect on vowel duration but when the results of unvoiced aspirated consonants are considered, the results are the contrary. There is obviously no difference in aspiration rather it be a voiced consonant or be it an unvoiced consonant (apart from the obvious difference of voicing) and from the basic knowledge of phonetics we also know that the characteristics of the consonants are carried over the aspiration, over to the vowels (the formants of the vowels change accordingly). So summing up the effect of

aspiration can said to be 0.55 % (Average for the voiced and unvoiced consonants). But we cannot, at all, say for definite that this is the actual effect of aspiration on duration. Perhaps some other method needs to be employed to find this or for using quasi minimal pairs the range for data finding would have to enlarged to allow greater data values.

8.1.5. Open versus Closed syllables:

In Dutch and Italian vowels in word-internal syllables have found to be longer than when the syllables were open. The same phenomenon was observed for English vowels (Santen 1992). This section investigates the effect of position of a vowel in a syllable with context whether it is an open syllable or a closed syllable for Urdu language.

A quasi minimal pairs analysis was performed for vowels, varying all the context except the open/close syllable to have generalized results. On average the duration of vowels was 4.28 % percent longer in closed syllables than in open syllables. This effect however varied over the vowels, for example for the long back low vowel /ɑ/ the difference in duration was 14.45 %, for the long back high vowel /u/, it was 11.14 % and for the long front low vowel /ae/ was found to be 19.56 %. No proper minimal set was found for the long front high vowel /i/ but an analysis with the intrinsic duration verified the same phenomenon as the other long vowels. These quasi minimal pairs have been shown in Appendix I. However the short vowels did not support this result very loudly but the general trend was followed. Even though the average value for the short vowels does not show a great inclination a look at the individual values verifies the trend.

Table 21: Percentage increase in the duration of vowels for vowels in closed syllables

Net % increase in vowel length in close syllables (Close vs Open)							4.28	
ɑ	u	i	æ	ã	ə	ʊ	ɪ	ɑẽ
14.45	11.14	-	19.56	-	-3.82	-	-1.52	-

8.1.6. Net results for Vowels:

It was observed that the maximum increase in majority of the cases was shown by the short vowel /ə/. The data for the nasal long vowel /ɑ̃/ and the diphthong /ɑẽ/ was rarely available, rather for /ɑ̃/ only data for the study of effect of voicing was available while for the diphthong /ɑẽ/ no data sets could be found. The long vowel /æ/ also did not have many data sets available.

Table 22: Net effect of different factors on vowel duration

	Stress	Preceding voiced consonant	Following voiced consonant	Closed vs Open	Pre-ceding voiced aspirated	Pre-ceding unvoiced aspirated	Word final
Net % Effect	8,90	12,76	17,68	4,28	1,11	12.85	28,83

Table 22 reports the net results obtained for different factors for the vowel duration analysis. The most significant factor in terms of its effect on vowel duration is the position in word (word final / word initial) and the factor of least significance is position in syllable (closed / open) . Although according to the Table 22, the effect of pre-ceding voiced aspirated consonant seems to be the least significant, but the results obtained for the factor of aspiration do not allow making any final comment. (See section 9.1.4)

8.2. Consonants:

A point of significance to be noted in the consonant analysis is that unlike vowel analysis the words are either 2 syllabic or three syllabic, whereas in the case of vowels all the words were strictly 2 syllabic except for the words for the analysis for number of syllables. Owing to this fact, a direct comparison does not exist between the analysis for vowels and consonants. All the other factors however were the same along with the external factors like speakers, and the methodology for duration extraction from speech files. The effect of the difference in number of syllables factor

can be eliminated by adding or subtracting the number of syllable factor from the values, however this is not very important as traditionally vowels and consonants are considered separate entities and in my opinion the results as they are suffice to exhibit the durational patterns of Urdu.

8.2.1. Position in word:

The factor position in word is defined for consonants as the position of the syllable containing the consonant in the word, i.e. word initial, word medial or word final. The words for the study of this factor were either 2 syllabic or 3 syllabic. The use of 4 syllabic words was avoided for two reasons, firstly Urdu has a very few 4 syllabic words and secondly all the 4 syllabic words found were the words imported from other languages, mostly English. The use of such words would not have yielded the true results as they were not truly Urdu words and their pronunciation often followed the rules of the native language, not Urdu (Or perhaps of none, i.e. neither Urdu nor the native language as the speakers were native Urdu speakers).

Table 23: Percentage increase in the duration of consonants at word final position

Net % Effect of position in word (Word final vs Non word final)											-2,52		
m	n	t	d	tʰ	dʰ	s	z	tʃ	dʒ	r	ɾ	l
-12,64	-16,59	-0,77	-8,74	-5,83	-27,30	14,09	0,09	-5,27	12,06	10,67	-16,76	-1,40

Table 24 shows the results of the duration analysis for consonants for the case of position in word. One can deduce by the negative value that consonants do not follow the famous word final lengthening rule, but the important factor to keep in mind is that 75% of the words in the analysis had the target consonant as the initial consonant of the word or the onset consonant of the first syllable. To be exact 52% of the words had the target consonant as the initial letter (consonant) of the word and 22% had the target consonant as the coda consonant of the first syllable. So the data set actually gives us the result that the duration of word initial consonants is the longest rather

than the word final consonants. Also the duration of the consonant is longest when it is at the beginning of the word. For the manifestation of this result refer to the Appendix N.

The results obtained are in accordance to what have been found for other languages. Quené (1999) showed that in Dutch, not only word initial consonants are longer than word final consonants but also that lengthening of the initial consonant can serve as a perceptual cue to Dutch word boundaries.

An explanation of this behaviour from the point of view of phonetics is given in (Patrice 2001) which says that "In initial position, the glottal opening gesture for consonant is longer and greater. Vowels are glotalized or pre-ceded by a glottal stop. Labial muscular activity in initial consonants is greater. The velum is higher in initial oral and nasal consonants. The tongue is higher and lingua palatal pressure greater in consonants. "(Patrice 2001)

Table 24: Percentage increase in the duration of consonants at word initial position

Net % Effect of position in word (Word initial / Non word initial)											10,49	
m	n	t	d	tʰ	dʰ	s	z	tʃ	dʒ	r	ɾ	l
15,13	21,68	11,30	13,86	53,73	46,45	-10,45	0,88	9,57	9,57	-5,02	31,83	5,39

Thus restating the results in terms of the correct factor for the consonants, i.e. word initial position for consonants, we get the results reported in Table 24 consequentially making this factor the third most significant factor for consonant duration.

8.2.2. Effect of Stress:

A study done by Thomas H. Crystal in 1987, (Thomas, Arthur 1987), on the effect of stress on vowel and consonant durations found almost the same trends for both the vowels and consonants. This study reports and verifies the same trend for Urdu.

The effect of stress on the duration of consonants, like that of vowels was found to be positive amounting to 7.24 % on average. The average effect on nasals was found to be 3.05 %, 2.18 % on stops, 32.23 % on aspirated stops and a negative value, i.e. decrease in the case fricatives of -1.21 %, a value small enough to be considered zero or no effect.

Table 25: Percentage increase in the duration of consonants in a stressed syllable

Net % increase in the duration of consonant in a stressed syllable											7,24	
m	n	t	d	tʰ	dʰ	s	z	tʃ	dʒ	r	ɾ	l
2,89	3,23	-18,40	22,76	19,98	44,60	2,29	-4,71	8,18	12,06	13,49	6,91	6,16

The quasi minimal pairs analysis done for this factor (stress) is given in appendix K.

8.2.3. Position in syllable:

While a vowel exists as the nucleus of a syllable, consonants can have two positions, coda or onset. The syllable is believed to consist of an obligatory nucleus preceded by an optional consonantal onset and followed by an optional consonantal coda (Kenstowicz, 1994, p. 252). Thus a consonant is said to be an onset consonant if it occurs at the start of the syllable, i.e. before the nucleus, whereas a coda consonant occurs after the nucleus or at the end of the syllable. Urdu does not allow complex onsets (onsets having more than one consonant) to occur, however, complex codas are allowed. (Ghazali M 2001) (Akram B 2001).

Table 26: Percentage increase in the duration of consonants when occurring in coda position

Net % increase in consonant duration (Coda vs Onset)											24,38	
m	n	t	d	tʰ	dʰ	s	z	tʃ	dʒ	r	ɾ	l
16,86	36,50	2,98	79,83	-25,92	-46,30	-26,83	23,83	75,53	55,47	11,34	-11,30	27,37

The results of this study indicate that position of a consonant in a syllable has a very significant effect on consonant duration. In fact this is the factor with the highest effect on consonant duration according to this study. According to the results, a consonant occurring at the coda position is 24.38% longer than a consonant occurring at onset position. The average percentage increase exhibited by the nasals was 26.68%, 41.41% by the stops, -36.11% by the aspirated stops, and -1.5% by the fricatives. All the consonants show a positive trend. The negative values for aspirated stops and the fricative /s/ is well explained by a look at the quasi minimal pairs given in the Appendix M. For the aspirated stops, in case of /d̪ʰ/, all the quasi minimal pairs have uni-syllabic words and this fact on its own explains the results. In case of /tʰ/, most of the quasi minimal pairs are uni-syllabic with two two-syllabic quasi minimal pairs. and in these cases, the consonant under consideration is the word final consonant for the coda position, and the word initial consonant for the onset position and we have already seen that in case of consonants word initial consonants are longer than word final consonants (see the section 9.2.2. Position in word for further details) .So this explains the results obtained.

8.2.4. Number of syllables:

As has been reported by literature, number of syllables in a word has a significant effect on segment duration. A segment in a uni-syllabic word tends to be longer than in a bi-syllabic word. As has been reported by (Redford A 2003) Segment duration varies with syllable structure, resulting in word-level duration patterns. These patterns provide important phonetic cues to syllable and word boundaries in English. Also Syllable position has a significant effect on the consonant duration in British English (Botinis et. al.).

This section reports the effect of Number of syllables on the duration of Urdu consonants. As was expected, the number of syllables in a word effect the duration of a consonant considerably. This factor is the second most significant factor found by this study, with respect to its effect on the duration of consonants. The net percentage increase in duration exhibited by consonants, when in

a word with lesser syllables was found to be 12.96 %. Almost all the consonants exhibited the same trend with only one exception of /tʃ/, which showed a minor negative trend, which can be considered negligible; however a discussion on the reason will be done in the following paragraphs. The results of the study, in terms of the net effect and the effect in individual cases are shown in Table 27.

Table 27: Percentage increase in the duration of consonants depending upon number of syllables

Net % increase in consonant duration (No. of syllables)													12,96
	m	**n**	**t**	**d**	**tʰ**	**dʰ**	**s**	**z**	**tʃ**	**dʒ**	**r**	**ɾ**	**l**
Net	13,76	13,75	7,13	18,62	41,64	15,90	24,85	8,17	-1,42	3,32	10,25	6,07	12,90
1 vs 2	23,03	15,99	-7,33	18,11	54,62	20,67	20,07	4,03	-15,83	10,61	9,61	8,02	25,09
2 vs 3	12,40	12,06	17,66	-0,65	11,47	19,07	15,33	19,08	10,11	-4,16	6,01	17,11	-0,01
1 vs 3	6,95	12,06	9,41	43,08	70,29	-4,76	43,89	-5,86	10,11	7,20	16,82	-9,94	18,77

The net effect for nasals was found to be 13.75 %, 12.9 % for stops, 28.8 % for aspirated stops and 16.51% for fricatives. The highest increase in duration was exhibited by aspirated stops, while the lowest (with exception of /tʃ/) was exhibited by the approximant /j/. These trends are shown graphically in figure 13.
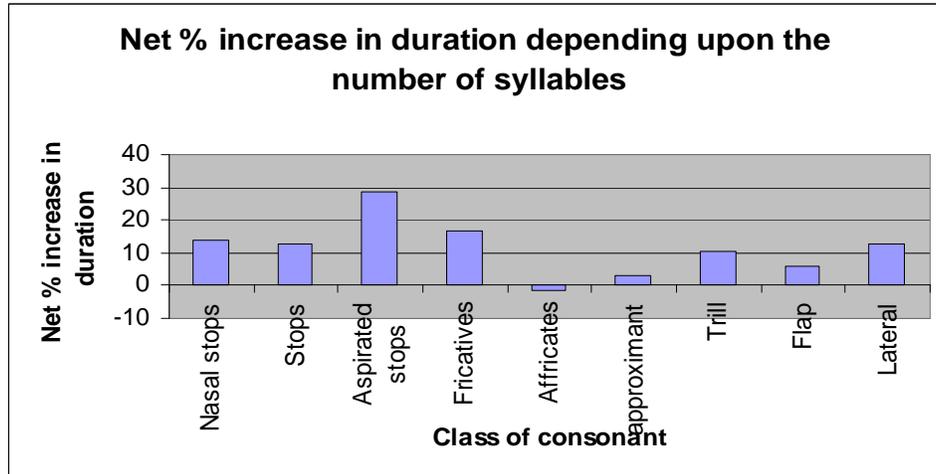
Figure 13: Percentage increase in the duration of consonants depending upon number of syllables

Exploring the quasi minimal pairs (given in appendix O), for the negative value for /tʃ/, it was found that it was mainly due to two reasons. Firstly the factor of word initial lengthening for consonants (section 9.2.2. Position in word) and for all the remaining cases, one of the words was either an imported word (words imported/adapted from other languages) or was rarely used in everyday language. For a discussion on the first case (see section 9.2.2.Position in word), whereas in case of words rarely used in everyday life, the speakers generally tend to elongate the words.

8.2.5. Open versus Closed syllables:

A quasi minimal pairs analysis was performed for consonants in the same manner as for the vowels, varying all the context except the open/close syllable to have generalized results. The trend of result obtained for the consonants was much similar to that for vowels i.e. that the duration of consonants was longer in closed syllables than in open syllables. The percentage difference in duration in closed syllables on average was 2.07 % for consonants as compared to vowels which was 4.28 %. This change is however not generalized over all manners of articulation as is obvious from the Table 23 that the trill /r/, the retroflex /ɽ/ shows a negative value. The negative value for the approximant /tʃ/ is negligible and we can easily conclude that it

is unaffected by its position in syllable, whether open or close. The final results are shown in table 23 and the detailed quasi minimal pairs analysis is given in Appendix N.

Table 28: Percentage increase in the duration of consonants in closed syllables

Net % increase in consonant duration (Close vs Open syllable)											2,07	
m	n	t	d	t^h	d^h	s	z	tʃ	dʒ	r	ɾ	l
24,35	-11,89	50,94	-12,43	0,44	-12,88	0,50	-0,07	-0,07	3,89	-4,18	-5,95	10,67

The average difference in duration for the nasals was found to be 6.23 %, to put in other words, the nasals exhibited an increase in duration of about 6.23 % when they occurred in closed syllables as compared to open syllables. For the stops /t/ and /d/ chosen for the analysis this difference was 19.26 %. In case of the aspirated stops /th2/ and /dh2/, a negative value of -6.22 % was found, the major contribution in this negative value being that of /dh2/ as /th2/ showed a positive trend. However an in-depth look at the quasi minimal pairs for the two aspirated stops reveals one out of three positive values for both (refer Appendix N).

8.2.6. Net Results for Consonants:

In general the highest increase for all factors was shown by the aspirated stops with the exception of the factor position in syllable (onset versus coda), in which case the highest increase was shown by the stops.

Table 29: Net effect of different factors on consonant duration

	Stress	Position in word (Word initial vs Non word initial	Position in syllable (Onset / Coda)	Open / Close syllable	Number of syllables
% increase	7,24	10,49	24,38	3,42	12,96

Table 29 reports the net results obtained for different factors for the consonant duration analysis. The most significant factor in terms of its effect on consonant duration is the position in syllable (Onset / Coda) and the factor of least significance is position in syllable (closed / open). The factor of least significance was found to be the same for both vowels and consonants. In terms of the factor position in word (word final / word initial) for vowels the most significant position in terms of greatest increase in duration was found to the word final position, the converse was found for consonants, i.e. the position of the greatest significance in terms of the greatest increase in duration was the word initial position.

9. Modeling with the Sum of Products Model (SOP):

Sum-of-products models are actually characterized as variants of the analysis of variance model where interaction terms are assumed to be products of single-factor scales and where the assumption that main effects and interaction terms have zero sums is dropped (Santen 1993).

As already discussed in the "literature review" and the "properties of segmental data" section that ordinal structure characterised by single-factor independence and amplificatory violations of joint independence is common in segmental duration data, so the model should be capable to fully capture these properties. Sum-of-products models can capture this important ordinal structure in a natural manner.When all scales are non-negative and the values of all scales for the same scale are ordered the same way, then single-factor independence automatically follows. A point of theortetical interest is that sums-of-products models are related to and in most respects generalize, several existing models. It is not surprising that Klatt's duration model is also a sum-of-products model.(Santen 1993)

9.1. Model for Vowels:

The sum-of-products model used for vowels is based on the Klatts' model adding the manner of stress and the type of syllable containing the vowel (open/close). The model used for vowels as reported in (Febrer, A. et. al.) and used is

$$D(v,a,c,p,s) = S_{1,1}(v) + S_{2,1}(v,a) + S_{3,1}(v) \ S_{3,2}(p) \ S_{3,3}(c) \ S_{3,4}(s)$$

where

v = Vowel identity,

a = Stress (stressed, unstressed),

p = Position in word (word final/ word initial),

c = Class of post-vocalic phone (voiced, voiceless),

and s = Syllable type (Open/Close).

The parameters used for modelling had been obtained during the study of durational behavior of Urdu vowels and consonants. The model parameters used are shown in the table 30 below:

Table 30: Parameters of sum-of-products model for vowels

Vowel	$S_{1,1}$	$S_{2,1}$	$S_{3,1}$	$S_{3,2}$	$S_{3,3}$	$S_{3,4}$
ɑ	125.44	9.01	2.37	0.90	0.63	0.87
u	126.57	**8.90**	5.12	0.34	0.10	0.11
i	111.58	8.06	2.22	**1.73**	0.24	**0.26**
æ	132.27	**8.90**	5.28	**1.73**	**1.06**	0.19
ə	69.59	14.71	0.83	0.49	0.43	3.82
ʊ	70.39	3.13	4.60	0.14	0.10	**0.26**
ɪ	56.59	5.54	1.75	0.28	**1.06**	1.52

For the cases of missing parameter of any vowel, the respective value of that factor from the combined effect has been used. But since the missing parameter values were because of the holes in data, which in turn depicts the scarcity of the particular feature in the particular vowel in Urdu language, so experimentation with the values has shown that using half the value of combined effect gives better results.

The duration prediction done with the SOP model for Urdu gives very satisfactory results, where each time the value predicted by the model falls in the acceptable range of values of actual speech. The complete results for each vowel are in given in Appendix P.

9.1.1. The statistical analysis of the SOP model for vowels:

The precision of the SOP model used for vowels was verified employing the standard statistical method, the analysis of variance. A summary of the results as illustrated by ANOVA is given in the table 31, the respective ANOVA tables have been reported in the appendix Q. The data for the duration of each word corresponding the seven vowels as spoken by six different speakers and the duration value of the same word as predicted by the SOP model was analysed by analysis of variance. The results in table 31 do not show any significant difference when compared to the F crit value, which clearly indicates that the SOP model successfully predicts reliable values of duration.

Table 31: ANOVA results for vowels

Source of Variation	SS	df	MS	F	P-value	F crit
ɑ	4840.97	5.00	968.19	4.63	0.00	2.30
u	2660.48	5.00	532.10	1.91	0.11	2.37
i	2045.79	5.00	409.16	1.67	0.16	2.41
ae	159.16	5.00	31.83	0.07	1.00	2.62
ə	1773.14	5.00	354.63	2.82	0.02	2.28
ʊ	2297.82	5.00	459.56	6.07	0.00	2.30
ɪ	698.35	5.00	139.67	2.66	0.03	2.34

9.2. Model for Consonants:

Because of the differnce in nature of vowels and consonants, differenrt Sum of Products (SOP) models need to be used for consonants (Febrer, A. et. al.).The sum-of-products model used for consonants is

$$D(c,a,p,r) = S_{1,1}(c) + S_{2,1}(c,a) + S_{3,1}(c) \, S_{3,2}(p) \, S_{3,3}(r)$$

where

c = Consonant identity,

a = Stress (stressed, unstressed),

p = Position in word (word final/ word initial),

and r = Position in syllable (Onset/Coda).

The respective parameter values for consonants are given below in table 32:

Table 32: Parameters of sum-of-products model for consonants

Consonant	$S_{1,1}$	$S_{2,1}$	$S_{3,1}$	$S_{3,2}$	$S_{3,3}$
m	89.35	2.89	1.43	0.91	1.01
n	86.41	3.23	2.86	1.30	2.19
t	16.68	18.40	12.61	0.68	0.18
d	20.02	22.76	6.26	0.83	4.79
tʰ	49.38	19.98	11.04	3.22	1.56
dʰ	56.70	44.60	4.54	2.79	2.78
s	92.94	2.29	2.67	0.63	1.61
z	65.14	4.71	1.60	0.05	1.43
tʃ	50.70	8.18	8.74	0.57	4.53
dʒ	38.57	12.06	7.57	0.57	3.33
r	41.23	13.49	2.63	0.30	0.68
ɾ	31.66	6.91	0.17	1.91	0.68

| l | 76.71 | 6.16 | 0.87 | 0.32 | 1.64 |

The results obtained using this model were also very satisfactory and most of the time lied in the range of acceptable values of the duration of the consonant. The detailed results for each consonant can be seen in Appendix Q.

9.2.1. The statistical analysis of the SOP model for consonants:

To verify the correctness of the SOP model, the ANOVA was applied on the data of the durations predicted by the SOP model and the average durations of each word representing the corresponding consonant as spoken by six different speakers. The results obtained from the analysis as given in the table 33 below show the reliable predictability of consonant duration by the SOP model as no significant difference is observed between the F and F crit values.

Table 33: ANOVA results for consonants

Source of Variation	SS	df	MS	F	P-value	F crit
m	494.70	5.00	98.94	1.37	0.26	2.53
t	1070.04	5.00	214.01	1.07	0.40	2.53
tʰ	1208.90	5.00	241.78	0.79	0.57	2.53
s	611.87	5.00	122.37	0.94	0.47	2.53
tʃ	6413.42	5.00	1282.68	7.90	0.00	2.53
r	2084.42	5.00	416.88	3.11	0.02	2.53
ɾ	3694.20	5.00	738.84	0.80	0.59	4.39
n	326.49	5.00	65.30	0.67	0.65	2.53
d	879.68	5.00	175.94	0.77	0.58	2.53
dʰ	1588.00	5.00	317.60	0.87	0.52	2.77
z	586.80	5.00	117.36	2.54	0.05	2.53

dʒ	432.74	5.00	86.55	0.80	0.56	2.53
l	188.30	5.00	37.66	0.54	0.74	2.53

The complete tables of the ANOVA analysis for the individual consonants are given in the appendix R.

10. Future Work:

Though this study provides a comprehensive durational study and the duration model for Urdu, but the results are only confined to word level, thus leaving further great ventures to be made in this domain specially at the sentence level. A comprehensive analysis of the language needs to be done using standard sentence corpora and using enough repetitions to capture the durational aptitudes of the segments of Urdu at phrase level. More possible studies involve study of phrase final lengthening, percentage change in word final lengthen for words greater than 2 syllables. When studying the effect of post and pre vocalic consonant, further levels like manner and place of articulation can be studied. Effect of manner and place for consonants also needs to studied.

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12. APPENDICES

Appendix A: Average Intrinsic Durations

	Average duration values for intrinsic duration calculation (Each value for each speaker is an average of 24 duration values)								
Phone	Word	Awais	Shakeel	Raheel	Irfan	SS	Farooq	Avg	std dV	% Deviation
b	صابر	86,89	100,38	83,99	93,63	90,42	90,54	90,97	2,58	2,84
m	جامن	79,25	84,07	69,39	81,66	77,57	84,20	79,35	5,54	6,98
ṯ	قاتل	106,68	105,61	113,58	106,14	108,62	116,81	109,57	8,84	8,07
ḍ	چادر	104,80	91,70	73,23	98,25	89,91	80,34	89,70	2,05	2,29
dʰ	سادهن	89,78	86,52	81,02	88,15	85,77	99,74	88,50	7,79	8,80
n	دانش	70,57	61,08	66,16	65,82	65,93	68,77	66,39	4,18	6,30
t	ناٹک	108,20	96,85	96,58	102,52	100,54	124,88	104,93	7,44	7,09
k	نوكر	120,16	130,44	113,37	125,30	121,32	108,66	119,88	4,87	4,06
g	ساگر	92,31	95,72	74,09	94,01	87,37	77,19	86,78	2,63	3,03
ŋ	آنگن	113,76	115,25	105,23	114,50	111,41	138,19	116,39	9,52	8,18
q	عاقل	126,26	115,08	129,63	120,67	123,65	145,46	126,79	5,74	4,52
f	كافر	94,81	125,89	116,10	110,35	112,26	126,42	114,30	3,49	3,06
w	كاوش	55,68	66,96	60,99	61,32	61,21	73,00	63,19	6,00	9,50
s	موسم	104,95	127,45	98,56	116,20	110,32	112,38	111,64	2,33	2,09
ʃ	هاشم	100,35	117,83	109,44	109,09	109,21	118,18	110,68	4,24	3,83
χ	داخل	105,39	110,63	101,77	108,01	105,93	126,79	109,75	6,75	6,15

h	ساحل	71,35	86,56	74,14	78,95	77,35	70,22	76,43	10,39	13,59
dʒ	کاجل	94,72	88,46	90,24	91,59	91,14	93,34	91,58	4,40	4,80
l	مالک	64,42	72,93	77,88	68,67	71,74	68,28	70,65	5,02	7,11
p	چاپڑ	121,71	135,17	110,74	128,44	122,54	138,85	126,24	7,42	5,88
pʰ	داپھڑ	147,68	108,89	138,45	128,28	131,67	158,02	135,50	-	-
bʰ	دوبھر	87,68	84,25	92,61	85,96	88,18	104,32	90,50	-	-
mʰ	جیمھر	110,40	127,29	103,62	118,85	113,77	-	127,54	-	-
t̪ʰ	گاتھک	114,77	114,89	136,06	114,83	121,91	157,35	126,63	-	-
d	میڈم	64,58	59,34	70,98	61,96	64,97	61,29	63,85	4,64	7,26
tʰ	بیٹھک	89,61	94,40	101,35	92,01	95,12	115,92	98,07	-	-
dʰ	چوڈھل	61,87	94,04	73,55	77,95	76,49	108,41	82,05	13,68	16,67
kʰ	چوکھٹ	113,90	122,71	130,82	118,31	122,48	121,28	121,58	9,05	7,44
gʰ	جیگھڑ	81,92	99,44	83,72	90,68	88,36	115,94	93,34	-	-
z	لازم	72,48	80,35	72,21	76,42	75,01	81,45	76,32	7,14	9,36
ɣ	ساغر	-	-	77,86	-	-	83,25	80,56	-	-
tʃ	ماچس	105,11	121,05	109,14	113,08	111,77	111,29	111,91	6,90	6,17
tʃʰ	باچھل	128,73	105,59	137,09	117,16	123,81	169,51	130,32	11,37	8,72
dʒʰ	اوجھل	108,37	88,00	83,66	98,19	93,34	120,34	98,65	5,75	5,83
r	چورس	22,11	27,75	19,30	24,93	23,05	19,67	22,80	6,31	27,69
ɾ	گوڑل	40,36	30,81	30,15	35,59	33,77	26,38	32,84	-	-
ɾʰ	کوڑھن	25,41	25,19	50,37	25,30	33,66	-	31,98	-	-

j	یاد	-	-	88,74	-	88,74	71,69	80,21	-	-
l^h	پیلهڑ	91,80	86,82	90,14	89,31	89,59	-	89,53	-	-
n^h	دمنها	84,81	183,55	180,37	134,18	149,58	-	146,50	-	-
ʒ	ژاله باری	64,70	93,83	79,06	79,26	79,19	96,63	82,11	9,01	10,97
r^h	دهارهی	30,78	61,43	23,76	46,11	38,66	-	40,15	-	-
ʕ	ساعت	-	-	102,16	-	102,16	102,19	102,18	-	-
ɑ	ٹاکی	120,21	120,57	139,54	120,39	126,77	110,96	123,07	1,66	1,35
o	ٹوکا	118,94	115,49	87,45	117,21	107,29	102,90	108,21	12,96	11,98
i	ٹیکا	112,58	116,50	103,33	114,54	110,80	98,40	109,36	3,19	2,92
u	کوٹا	142,07	118,56	116,14	130,32	125,59	96,00	121,45	7,50	6,18
ɔ	پودا	155,01	114,10	128,34	134,56	132,48	100,92	127,57	-	-
æ	پیدا	141,11	126,63	127,80	133,87	131,85	100,72	126,99	4,79	3,77
e	ٹیکا t eka	111,73	121,79	109,62	116,76	114,38	103,35	112,94	3,42	3,03
ə	کَٹا	56,07	83,37	69,22	69,72	69,55	64,67	68,76	5,64	8,19
ɪ	ٹِکا	50,32	65,91	52,35	58,12	56,19	46,13	54,84	4,48	8,17
ʊ	ٹُکا	66,89	85,43	54,30	76,16	68,87	43,09	65,79	6,42	9,76
ã	ماں	211,70	212,13	152,48	211,91	192,10	233,50	202,30	30,76	15,20
õ	ہوں	268,39	205,45	196,68	236,92	223,51	231,48	227,07	-	-
ĩ	لِیں	268,18	212,81	213,78	240,50	231,59	208,93	229,30	-	-
ũ	لُوں	224,71	219,04	193,92	221,87	212,56	173,67	207,63	-	-

æ̃	ہیں	188,35	213,64	171,06	200,99	191,02	221,00	197,68	37,38	18,91
ẽ	میں	224,42	206,24	165,54	215,33	198,73	181,34	198,60	12,01	6,05
ɪũ	کیوں	266,37	231,53	185,57	248,95	227,82	173,86	222,35	10,12	4,55
əe	گئے	234,96	220,94	224,75	227,95	226,88	241,03	229,42	2,18	0,95
əe	کئی	245,40	225,27	206,31	235,33	225,66	243,60	230,26	4,28	1,86
ɑo	تاؤ	235,62	254,42	264,37	245,02	251,47	248,91	249,97	7,50	3,00
ɑi	تائی	238,39	242,81	257,97	240,60	246,39	264,46	248,44	12,59	5,07
ɑe	تائے	215,13	252,25	266,22	233,69	244,53	256,91	244,79	26,97	11,02
eɑ	گیا	264,76	250,71	221,04	257,73	245,50	259,14	249,81	9,09	3,64
oi	کوئی	202,06	227,44	227,39	214,75	218,96	241,49	222,01	43,98	19,81
ɑẽ	کھائیں	267,17	259,15	262,38	263,16	262,90	271,00	264,29	12,75	4,83
oe	کھوئے	216,89	206,70	221,00	211,79	214,86	229,84	216,85	10,56	4,87
əĩ	گئیں	270,58	231,68	203,99	251,13	235,41	338,15	255,15	-	-
ɪɑ	کیا	286,88	267,15	-	277,01	277,01	224,04	263,77	-	-
ɑũ	کھاؤں	224,85	199,00	128,41	211,92	184,08	266,71	202,49	-	-

Appendix B: Diphthong Study

Word	Diphthong and its duration	Independant duration of first vowel in diphthong	Independant duration of second vowel in diphthong	Added duration		Percentage difference
کیوں	ɪũ	ɪ	ũ	ɪ plus ũ		

	232,22	56,59	214,50	271,09		16,74
گئے	əe	ə	e	ə plus e		
	227,10	69,59	114,87	184,46		-18,78
کیوں	ɪũ	ɪ	ũ	ɪ plus ũ		
	232,22	56,59	214,50	271,09		16,74
گئے	əe	ə	e	ə plus e		
	227,10	69,59	114,87	184,46		-18,78
تائی	ɑi	ɑ	i	ɑ plus i		
	245,18	125,44	111,58	237,02		-3,33
تائے	ɑe	ɑ	e	ɑ plus e		
	242,27	125,44	114,87	240,31		-0,81
گیا	eɑ	e	ɑ	e plus ɑ		
	248,05	114,87	125,44	240,31		-3,12
کوئی	oi	o	i	o plus i		

	218,08	111,58	111,58	223,16		2,33
کھائیں	ɑẽ	ɑ	ẽ	ɑ plus ẽ		
	262,96	125,44	202,19	327,63		24,60
کھوئے	oe	o	e	o plus e		
	214,22	111,58	114,87	226,45		5,71
گئیں	əĩ	ə	ĩ	ə plus ĩ		
	238,69	69,59	233,45	303,03		26,96
کیا (ki a)	ɪɑ	ɪ	ɑ	ɪ plus ɑ		
	277,01	56,59	125,44	182,03		-34,29
کھاؤں	ɑũ	ɑ	ũ	ɑ plus ũ		
	189,88	125,44	214,50	339,94		79,02

Appendix C: Average Durations for Vowels

Word	Vowel		Nakhat	Raheel	Shanza	Awais	Kiran	Farooq		Average	Std dev
			Average duration values (in ms) for vowel duration analysis (Each value for each speaker is an average of 24 duration values)								
کُوٹا	u		114,65	64,50	114,65	89,58	85,31	87,21		92,65	19,25
	ɑ		129,06	128,89	129,06	128,98	141,82	139,31		132,85	6,02
کاتِب	ɑ		112,55	106,81	112,55	109,68	99,93	102,75		107,38	5,22
	ɪ		59,76	44,59	59,76	52,18	61,67	73,77		58,62	9,79
کِیکر	i		101,70	75,32	101,70	88,51	75,30	72,67		85,87	13,46
ٹانکا	ɑ		132,39	129,52	132,39	130,96	171,03	159,47		142,63	17,93
کتُّر	ʊ		48,83	43,51	48,83	46,17	44,56	36,24		44,69	4,68
قَتل	ə		63,32	44,52	63,32	53,92	56,82	35,64		52,92	10,97
پیدل	æ		92,28	115,44	92,28	103,86	113,70	93,90		101,91	10,73
پاگَل	ɑ		133,47	131,11	133,47	132,29	134,17	109,26		128,96	9,71
کانا	ã		137,28	120,16	137,28	128,72	129,29	109,63		127,06	10,66
کَدہ	ə		67,88	59,30	67,88	63,59	71,27	51,79		63,62	7,12
	ɑ		134,34	120,09	134,34	127,22	183,57	132,19		138,62	22,68
پدر	ɪ		55,13	60,37	55,13	57,75	67,78	46,61		57,13	6,97
ڈاکا	ɑ		126,92	116,37	126,92	121,65	127,35	108,83		121,34	7,48
گیتوں	i		115,42	90,34	115,42	102,88	100,73	106,18		105,16	9,55
ڈانٹا	ã		161,65	127,94	161,65	144,79	183,91	146,60		154,42	19,13
بُتوں	ʊ		61,72	56,14	61,72	58,93	59,69	33,44		55,27	10,89
گَتَّر	ə		84,48	66,35	84,48	75,42	81,58	69,91		77,04	7,74
بیٹھک	ə		62,28	66,26	62,28	64,27	68,65	60,22		63,99	3,07
	æ		105,51	116,21	105,51	110,86	113,39	102,07		108,92	5,42
پِٹھا	ɪ		53,96	46,74	53,96	50,35	54,82	51,72		51,93	3,04
دوپیوں	u		126,18	102,63	126,18	114,41	96,33	109,50		112,54	12,21
کُوٹنا	u		105,45	85,72	105,45	95,59	107,50	118,09		102,97	11,08
کاٹنا	ɑ		118,55	118,90	118,55	118,73	149,79	149,69		129,04	16,04
ٹُکنا	ʊ		47,56	45,90	47,56	46,73	46,94	32,78		44,58	5,81
تَکڑا	ə		46,41	57,48	46,41	51,95	52,91	39,13		49,05	6,43
کِتنا	ɪ		38,97	33,58	38,97	36,28	47,30	30,70		37,63	5,72
تکرَار	ə		51,42	45,43	51,42	48,43	51,77	40,60		48,18	4,45
ٹِکیا	ɪ		50,82	36,16	50,82	43,49	58,55	37,81		46,28	8,65
موکَّد	ə		71,13	63,97	71,13	67,55	96,35	72,28		73,73	11,50
مَکتب	ə		60,54	55,36	60,54	57,95	63,04	64,37		60,30	3,29
ترکِیب	i		123,63	119,17	123,63	121,40	128,78	141,45		126,34	8,06
لاگَت	ə		73,38	69,74	73,38	71,56	89,29	68,42		74,30	7,61
ثابِت	ɪ		56,79	59,67	56,79	58,23	72,28	76,39		63,36	8,67

لبیک	æ	152,17	142,50	152,17	147,33	186,49	148,74	154,90	15,89
چابُک	ʊ	55,19	55,30	55,19	55,25	76,40	40,77	56,35	11,40
تھُو کا	u	98,29	63,44	98,29	80,86	77,16	73,27	81,88	13,97
کھا تا	ɑ	104,02	93,39	104,02	98,71	86,08	76,81	93,84	10,79
پِھٹا	ə	62,88	62,64	62,88	62,76	69,09	49,10	61,56	6,61
پِھٹا	ɪ	65,14	57,96	65,14	61,55	73,84	47,35	61,83	8,84
ٹُھکا	ʊ	59,03	41,87	59,03	50,45	63,16	40,16	52,28	9,68
تَھکا	ə	78,54	58,78	78,54	68,66	78,74	48,60	68,64	12,63
دکھائیں	ɑ̃	285,67	227,73	285,67	256,70	251,68	282,80	265,04	23,69
رکھی	i	77,16	78,75	77,16	77,96	103,29	90,92	84,21	10,75
کُھدتا	ʊ	45,65	52,46	45,65	49,05	53,36	55,42	50,26	4,13
تَھپکا	ə	60,76	46,45	60,76	53,61	53,90	42,36	52,97	7,45
پِھٹکا	ɪ	68,11	41,25	68,11	54,68	74,13	48,53	59,14	12,95
کِھٹاک	ə	80,63	50,03	80,63	65,33	56,65	46,61	63,31	14,86
کتَھک	ə	78,60	70,91	78,60	74,76	91,10	54,97	74,82	11,86
ڈھاکہ	ɑ	115,89	122,83	115,89	119,36	100,42	71,48	107,65	19,31
گُھٹا	ʊ	68,09	52,20	68,09	60,14	61,43	57,11	61,18	6,22
گُھٹا	ə	80,19	69,87	80,19	75,03	86,55	69,16	76,83	6,75
گِھٹور	ə	92,06	57,73	92,06	74,90	87,59	74,03	79,73	13,46
بِھکتو	ʊ	59,78	56,05	59,78	57,92	74,86	37,01	57,57	12,12
گِھپلا	ə	64,77	57,02	64,77	60,89	81,41	55,58	64,07	9,31
دُھتکار	ʊ	70,65	65,24	70,65	67,95	79,34	76,76	71,76	5,33
ڈاکو	ɑ	125,78	115,36	125,78	120,57	121,12	100,85	118,24	9,36
	u	101,31	74,80	101,31	88,06	97,93	87,49	91,82	10,39
گاتی	i	102,67	99,27	102,67	100,97	81,37	119,54	101,08	12,15
تاکید	ɑ	126,62	118,57	126,62	122,60	99,52	108,65	117,10	10,90
	i	118,18	112,10	118,18	115,14	156,59	159,61	129,97	21,93
پُکار	ʊ	51,86	35,86	51,86	43,86	51,28	28,81	60,39	33,53
پکاس	ɪ	50,29	47,25	50,29	48,77	44,01	33,44	45,67	6,44
کَپاٹ	ə	40,49	29,26	40,49	34,88	43,49	41,28	38,31	5,27
کرتوت	u	144,69	104,24	144,69	124,47	167,71	145,75	138,59	21,69
لوکاٹ	ɑ	158,61	150,92	158,61	154,76	203,03	200,64	171,09	23,99
کُکر	ʊ	53,75	51,84	53,75	52,80	45,89	40,76	49,80	5,32
پِھدک	ə	79,71	70,58	79,71	75,15	87,09	78,42	78,44	5,49
ٹیکسی	æ	98,55	67,70	98,55	83,12	99,40	71,20	86,42	14,53
دکھنا	ʊ	53,99	48,30	53,99	51,14	57,20	39,88	50,75	6,11
تِتلی	ɪ	46,39	67,54	46,39	56,97	54,06	48,57	53,32	8,18
دَھکا	ɑ	120,45	104,37	120,45	112,41	145,15	135,54	123,06	14,97
برکت	ə	58,38	57,74	58,38	58,06	66,43	69,54	61,42	5,18
پھٹاک	ɑ	117,06	123,31	117,06	120,19	182,39	183,33	140,56	32,85
تابُوت	ɑ	129,95	126,09	129,95	128,02	107,63	120,26	123,65	8,63

	u	125,03	116,21	125,03	120,62	153,84	137,58	129,72	13,80
بَدید	ə	57,17	53,26	57,17	55,22	63,47	49,47	55,96	4,68
ڈاکیا	ɑ	108,67	118,83	108,67	113,75	123,18	110,96	114,01	5,90
دُکان	ʊ	46,21	51,06	46,21	48,64	47,64	46,21	47,66	1,94
ڈکیت	ə	54,01	35,61	54,01	44,81	65,44	47,02	50,15	10,13
یِکھیر	ɪ	42,67	47,81	42,67	45,24	61,35	55,45	49,20	7,61
دیپال	i	103,87	88,84	103,87	96,35	58,04	82,10	88,85	17,33
داتری	ɑ	128,83	120,07	128,83	124,45	133,36	123,95	126,58	4,69
گَٹھلی	ʊ	63,55	55,19	63,55	59,37	79,21	47,55	61,40	10,59
بیٹھتے	æ	120,70	133,27	120,70	126,98	141,74	138,01	130,23	8,88
ٹِڈّا	ɪ	62,27	50,26	62,27	56,26	61,10	56,13	58,05	4,74
کدو	ə	54,25	53,97	54,25	54,11	64,91	52,55	55,67	4,57
	u	121,44	95,18	121,44	108,31	125,11	128,59	116,68	12,57
کُبڑا	ʊ	42,63	46,96	42,63	44,80	47,72	40,66	44,23	2,75
پادری	ɑ	131,30	130,02	131,30	130,66	140,59	135,68	133,26	4,11
مکتُوب	u	141,24	115,45	141,24	128,35	154,43	139,86	136,76	13,32
رکوُد	u	143,05	137,68	143,05	140,37	162,80	193,96	153,48	21,75
کُھدیڑ	ʊ	48,94	36,85	48,94	42,89	50,83	53,10	46,92	5,99
ٹِڈی	i	105,64	70,32	105,64	87,98	60,98	115,32	90,98	21,72
ٹِھگنا	ɪ	67,46	53,57	67,46	60,51	52,93	54,22	59,36	6,84
ٹَٹھور	ə	61,92	46,65	61,92	54,29	67,50	53,66	57,66	7,50
گدھا	ɑ	124,08	122,03	124,08	123,05	146,57	141,67	130,25	10,89
کبھی	i	132,43	105,58	132,43	119,00	121,43	141,58	125,41	12,73
ٹُھڈا	ʊ	59,01	37,01	59,01	48,01	57,02	50,14	51,70	8,57
کھَڈا	ə	60,03	60,84	60,03	60,44	69,39	41,45	58,70	9,20
ڈُوبتے	u	97,23	101,53	97,23	99,38	125,34	128,40	108,19	14,59
کُھبے	ʊ	53,50	39,65	53,50	46,58	56,77	33,38	47,23	9,16
کَٹ	ə	87,96	65,93	87,96	76,94	113,59	71,96	84,06	16,90
ٹِک	ɪ	62,43	63,14	62,43	62,79	83,91	57,37	65,35	9,34
گھُٹ	ʊ	88,16	81,88	88,16	85,02	119,32	78,57	90,18	14,75
ڈاک	ɑ	171,92	155,07	171,92	163,50	200,14	215,72	179,71	23,26
قید	æ	158,96	151,85	158,96	155,41	218,69	190,49	172,39	26,62
کی	i	143,99	116,94	143,99	130,47	160,30	154,23	141,65	15,83
کُوٹ	u	130,47	107,12	130,47	118,80	158,57	181,27	137,78	27,32
کَٹنا	ə	55,85	47,75	55,85	51,80	66,95	60,84	56,50	6,75
ٹِکنا	ɪ	47,54	41,77	47,54	44,66	51,16	35,57	44,71	5,47
گھُٹنا	ʊ	74,82	63,29	74,82	69,06	68,25	49,36	66,60	9,51
قیدی	æ	121,69	112,10	121,69	116,90	117,14	130,23	119,96	6,17
کَٹوانا	ə	55,87	34,36	55,87	45,12	62,24	47,85	50,22	9,92
ٹِکانا	ɪ	46,54	33,95	46,54	40,24	52,38	46,08	44,29	6,36
گھُٹوانا	ʊ	79,68	40,25	79,68	59,97	92,44	43,98	66,00	21,25

قیدیوں	æ	122,25	129,83	122,25	126,04	121,27	123,69	124,22	3,21
کیکروں	i	92,27	79,60	92,27	85,94	80,09	90,22	86,73	5,81
زکّوٹا	u	115,14	85,76	115,14	100,45	111,55	83,27	101,89	14,51
لادا	ɑ	107,26	110,83	107,26	109,04	121,56	123,52	113,24	7,35
لاشا	ɑ	129,18	108,78	129,18	118,98	124,72	113,83	120,78	8,39
لاچا	ɑ	126,96	101,10	126,96	114,03	114,15	112,93	116,02	9,79
لاحا	ɑ	121,95	119,41	121,95	120,68	117,07	115,31	119,40	2,72
لارا	ɑ	168,76	136,17	168,76	152,46	159,49	144,72	155,06	13,15
لاڑا	ɑ	128,79	137,38	128,79	133,09	163,21	151,37	140,44	13,95
پالا	ɑ	121,34	107,01	121,34	114,18	113,68	115,16	115,45	5,39
تالا	ɑ	158,34	117,91	158,34	138,13	127,34	108,68	134,79	20,70
ٹالا	ɑ	130,65	105,96	130,65	118,30	131,14	104,85	120,26	12,49
کالا	ɑ	130,95	104,78	130,95	117,86	116,23	117,06	119,64	9,98

Appendix D: Minimal Pairs (VOWELS for the factor "Stress")

Minimal Pairs for Vowel duration analysis for the factor "Stress"

Vowel	Word	Minimal Pairs				Duration in context	Intrinsic duration		Differnce	Percentage increase
ɑ	ڈاکا	str	open	V UV	non wf	121,34	125,44		4,24	3,62
	تاکید	unstr	open	UV UV	non wf	117,10				
ɑ	پاگل	str	open	UV V	non wf	128,96	125,44		5,31	4,29
	تابُوت	unstr	open	UV V	non wf	123,65				
ɑ	ڈاکا	str	open	V UV	non wf	121,33	125,44		7,32	6,42
	ڈاکیا	unst r	open	V UV	non wf	01.114				
ɑ	لوکاٹ	str	close	UV UV	wf	09.171	125,44		30,53	21,72
	پھٹاک	unstr	close	UV UV	wf	56.140				
ɑ	ٹانکا	str	open	V UV	non wf	142,62	125,44			
ɑ	کھا تا	str	open	UV UV	non wf	93,84	125,44			
ɑ	ڈھاکہ	str	open	V UV	non wf	65.107	125,44			

u	کوُٹا	str	open	V UV	non wf	92,64	126,57			
u	کدو	unstr	open	V UV	wf	116,68	126,57			
u	تھوُ کا	str	open	UV UV	non wf	81,88	126,57			
u	دوُپیوں	str	open	V UV	non wf	112,54	126,57			
u	کرتوُت	str	close	UV UV	wf	59.138	126,57			
u	کدو	unstr	open	V UV	wf	68.116	126,57			
i	گیتوں	str	open	V UV	non wf	105,16	111,58		16,31	18,36
	دِپال	unst r	open	V UV	non wf	88,85				
i	دِپال	unstr	open	V UV	non wf	85.88	111,58		-2,03	-2,23
	ٹِڈی	unstr	open	V UV	wf	98.90				
i	کِیکر	str	open	V UV	non wf	85,87	111,58			
i	ٹِڈی	unstr	open	V UV	wf	90,98	111,58			
i	رکھی	unstr	open	UV UV	wf	84,21	111,58		27,37	32,50
æ	پیدل	str	open	UV V	non wf	101,91	132,27			
æ	بیٹھک	str	open	V UV	non wf	108,92	132,27			
æ	لبیک	unstr	close	V UV	wf	154,90	132,27			
ã	کانا	str	open	UV V	non wf	127,05	196,23			
ã	ڈانٹا	str	open	V UV	non wf	154,42	196,23			
ə	کَدہ	str	open	UV V	non wf	63,61	69,59		7,70	13,77
	پَدید	unstr	open	UV V	non wf	55,91				

			str	open	V UV	non wf		52,92	69,59		14,61	38,14
ə		قَتل										
		کِپاٹ		unstr	open	UV UV	non wf	38,31				
ə		گَتَّر		str	open	V UV	non wf	77,04	69,59		26,89	53,62
		ڈکیت		unst r	open	V UV	non wf	50,15				
ə		تَھپکا		str	close	UV UV	non wf	52,97	69,59		-10,34	-16,33
		کھَٹاک		unstr	close	UV UV	non wf	63,31				
ə		پَھٹا		str	open	UV UV	non wf	61,56	69,59		-7,08	-10,31
		تَھکا		unstr	open	UV UV	non wf	68,64				
ə		گَّھٹا		str	open	V UV	non wf	76,83	69,59		-2,90	-3,64
		گھَٹّور		unstr	open	V UV	non wf	79,73				
ə		پُھدک		str	close	UV UV	wf	44.78	69,59		17,02	27,71
		برکت		unstr	close	UV UV	wf	42.61				
ə		لاگت		unstr	close	V UV	wf	74,30	69,59			
ə		ڈکیت		unstr	open	V UV	non wf	15.50	69,59			
ə		گھِپلا		str	close	V UV	non wf	07.64	69,59			
ə		کھَڈّا		str	open	UV V	non wf	70.58	69,59			
ʊ		کُھدیڑ		unstr	open	UV V	non wf	92.46	70,39		-0,31	0,65
		کُھبے		str	open	UV V	non wf	23.47				
ʊ		کتُّر		str	open	V UV	non wf	44,69	70,39		-15,70	-26,00
		پُکار		unstr	open	UV UV	non wf	60,39				
ʊ		بتُوں		str	open	V UV	non wf	55,27	70,39		7,61	15,97
		دُکان		unst r	open	V UV	non wf	47,66				
ʊ		چابُک		unstr	close	V UV	wf	56,35	70,39			
ʊ		کُھدتا		str	close	UV UV	non wf	26.50	70,39			
ʊ		گُّھٹا		str	open	V UV	non wf	18.61	70,39			

ʊ	کُکر		str	close	UV UV	wf		80.49	70,39			
ʊ	دُکان		unstr	open	V UV	non wf		66.47	70,39			
ʊ	ٹُھکا		unstr	open	UV UV	non wf		28.52	70,39		18,11	34,60
ɪ	بِٹھا		str	open	V UV	non wf		51,93	56,59		2,73	5,54
	یِکھیر		unst r	open	V UV	non wf		49,20				
ɪ	پِدر		str	open	UV V	non wf		57,13	56,59			
ɪ	ثاِبت		unstr	close	V UV	wf		63,36	56,59			
ɪ	پِھٹکا		str	close	UV UV	non wf		59,14	56,59			
ɪ	پِھٹا		str	open	UV UV	non wf		61,83	56,59			
ɪ	یِکھیر		unstr	open	V UV	non wf		20.49	56,59			
ɪ	پِکاس		unstr	open	UV UV	non wf		45,67	56,59		10,92	23,92
ɑ̃	دکھائیں		str	open	UV UV	wf		265,04	262,96			

Appendix E: Minimal Pairs (VOWELS for the factor "Effect of Voicing : Pre vocalic consonant")

Minimal Pairs for Vowel duration analysis for the factor "Pre-vocalic voiced consonant"											
Vowel	Word		Minimal Pairs					Duration in context	Intrinsic duration	Differnce	Percentage increase
ɑ	کاِتب		str	open	UV UV	non wf		107,38	125,44	13,96	13,00
	ڈاکا		str	open	V UV	non wf		121,34			
ɑ	ڈاکو		unstr	open	V UV	non		118,24	125,44		

					wf					
ɑ	کھا تا	str	open	asp UV	non wf	93,84	125,44	13,81	14,71
	ڈھاکہ	str	open	asp V	non wf	107,65			
ɑ	تاکید	unstr	open	UV UV	non wf	117,10	125,44	-3,09	-2,64
	ڈاکیا	unstr	open	V UV	non wf	114,01			
ɑ	کُوڑا	unstr	open	UV UV	wf	132,85	125,44	5,77	4,34
	کدہ	unstr	open	UV V	wf	138,62			
ɑ	لوکاٹ	str	close	UV UV	wf	171,09	125,44		
ɑ	پادری	str	close	UV V	non wf	133,26	125,44		
i	کِیکر	str	open	UV UV	non wf	85,87	111,58	19,29	22,47
	گیتوں	str	open	V UV	non wf	105,16			
i	گاتی	unstr	open	UV UV	wf	101,08	111,58		
i	دیپال	unstr	open	V UV	non wf	88,85	111,58		
u	کُوڑا	str	open	UV UV	non wf	92,65	126,57	19,89	21,47
	دُوپوں	str	open	V UV	non wf	112,54			
u	کرتُوت	str	close	UV UV	wf	138,59	126,57	-8,87	-6,40
	تابوت	str	close	V UV	wf	129,72			
u	ڈُوبتے	str	close	V V	non wf	108,19	126,57		
u	ڈاکو	unstr	open	UV UV	wf	91,82	126,57		
u	تھُو کا	str	open	asp UV	non wf	81,88	126,57		
æ	لبیک	unstr	close	V UV	wf	154,90	132,27		

æ	بیٹھک		str	open	V UV	non wf		108,92	132,27	-23,34	
ã	ٹانکا		str	open	UV UV	non wf		142,63	196,23	11,80	8,27
	ڈانٹا		str	open	V UV	non wf		154,42			
ɪ	پِکاس		unstr	open	UV UV	non wf		45,67	56,59	3,53	7,72
	یِکھیر		unstr	open	V UV	non wf		49,20			
ɪ	یِٹھا		str	open	V UV	non wf		51,93	56,59	-4,67	
ɪ	پِھٹا		str	open	asp UV	non wf		61,83	56,59		
ɪ	پِھٹکا		str	close	asp UV	non wf		59,14	56,59		
ɪ	ٹِڈا		str	close	UV V	non wf		58,05	56,59		
ʊ	پُکار		unstr	open	UV UV	non wf		60,39	70,39	-12,73	-21,08
	دُکان		unstr	open	V UV	non wf		47,66			
ʊ	کُھدتا		str	close	asp UV	non wf		50,26	70,39	7,30	14,53
	بُھکتو		str	close	asp V	non wf		57,57			
ʊ	کتُر		str	open	UV UV	non wf		44,69	70,39	10,58	23,68
	بُتوں		str	open	V UV	non wf		55,27			
ʊ	چابُک		unstr	close	V UV	wf		56,35	70,39		
ʊ	کُکر		str	close	UV UV	wf		49,80	70,39		
ʊ	گُھٹا		str	open	asp V	non wf		61,18	70,39		
ʊ	دُھتکار		unstr	close	asp V	non wf		71,76	70,39		

Vowel	Word							Duration in context	Intrinsic duration	Difference	Percentage increase
ʊ	کُبڑا		str	close	UV V	non wf		44,23	70,39		
ə	پَھٹا		str	open	asp UV	non wf		61,56	69,59	15,27	24,81
	گھٹا		str	open	asp V	non wf		76,83			
ə	تَھپکا		str	close	asp UV	non wf		52,97	69,59	11,10	20,95
	گھپلا		str	close	asp V	non wf		64,07			
ə	قَتل		str	open	UV UV	non wf		52,92	69,59	24,11	45,56
	گَٹَر		str	open	V UV	non wf		77,04			
ə	کپَاٹ		unstr	open	UV UV	non wf		38,31	69,59	11,83	30,89
	ڈکیت		unstr	open	V UV	non wf		50,15			
ə	کھَٹاک		unstr	close	asp UV	non wf		63,31	69,59		
ə	پُھدک		str	close	UV UV	wf		78,44	69,59		
ə	کدو		str	close	UV V	non wf		55,67	69,59		

Appendix E: Minimal Pairs (VOWELS for the factor "Effect of Voicing : Post vocalic consonant")

Minimal Pairs for Vowel duration analysis for the factor "Post-vocalic voiced consonant"											
Vowel	Word		Minimal Pairs					Duration in context	Intrinsic duration	Differnce	Percentage increase
ɑ	کاتِب		str	open	UV UV	non wf		107,38	125,44	21,58	20,10
	پاگل		str	open	UV V	non wf		128,96			
ɑ	تاکید		unstr	open	UV UV	non wf		117,10	125,44	6,56	5,60

	تابُوت	unstr	open	UV V	non wf	123,65			
ɑ	کدہ	unstr	open	V UV	wf	138,62			
ɑ	ڈاکو	str	open	V UV	non wf	118,24	125,44		
ɑ	لوکاٹ	str	close	UV UV	wf	171,09	125,44		
ɑ	داتری	str	close	V UV	non wf	126,58	125,44		
i	گاتی	unstr	open	UV UV	wf	101,08	111,58	25,26	24,99
	ترکیب	unstr	close	UV V	wf	126,34			
i	کِیکر	str	open	UV UV	non wf	85,87	111,58		
i	گاتی	unstr	open	UV UV	wf	101,08	111,58		
u	کرتُوت	str	close	UV UV	wf	138,59	126,57	14,89	10,75
	رکوُد	str	close	UV V	wf	153,48			
u	کوُٹا	str	open	UV UV	non wf	92,65	126,57		
u	ڈاکو	unstr	open	UV UV	wf	91,82	126,57		
u	ڈُوبتے	str	close	V V	non wf	108,19	126,57		
æ	پیدل	str	open	UV V	non wf	101,91	132,27		
æ	بیٹھتے	str	close	V UV	non wf	130,23	132,27		
ã	ٹانکا	str	open	UV UV	non wf	142,63	196,23	-15,57	-10,91
	کانا	str	open	UV V	non wf	127,06			
ə	قَتل	str	open	UV UV	non wf	52,92	69,59	10,70	20,21
	کَدہ	str	open	UV V	non wf	63,62			
ə	تکرَار	unstr	close	UV UV	non wf	48,18	69,59	25,56	53,04
	موکَد	unstr	close	UV V	wf	73,73			
ə	کِبَاٹ	unstr	open	UV UV	non wf	38,31	69,59	17,65	46,06
	بَدید	unstr	open	UV V	non wf	55,96			

ə	پُهدک	str	close	V UV	wf		78,44	69,59		
ə	مَکتب	unstr	close	UV V	wf		60,30	69,59		
ə	تَهکا	unstr	open	asp UV	non wf		68,64	69,59		
ʊ	ٹُهکا	unstr	open	asp UV	non wf		52,28	70,39	-5,36	-10,25
	کُهدیڑ	unstr	open	asp V	non wf		46,92			
ʊ	پُکار	unstr	open	UV UV	non wf		60,39	70,39		
ʊ	گُٹُهلی	str	close	V UV	non wf		61,40	70,39		
ʊ	کتُّر	str	open	UV UV	non wf		44,69	70,39		
ʊ	کُکر	str	close	UV UV	wf		49,80	70,39		
ɪ	پدر	str	open	UV V	non wf		57,13	56,59		
ɪ	ٹِکیا	unstr	close	UV UV	non wf		46,28	56,59		
ɪ	پکاس	unstr	open	UV UV	non wf		45,67	56,59		

Appendix F: Minimal Pairs (VOWELS for the factor "Effect of Aspiration (voiced)")

	Minimal Pairs for Vowel duration analysis for the factor "Aspiration (voiced)"									
Vowel	Word			Minimal Pairs				Duration in context	Intrinsic duration	Differnce	Percentage increase
ɑ	ڈاکا	str	open	V UV	non wf		121,34	125,44	13,69	12,72
	ڈهاکہ	str	open	asp V UV	non wf		107,65			
ɑ	داتری	str	close	V UV	non wf		126,58	125,44		

ɑ	گدھا		unstr	open	asp V nil	wf		130,25	125,44			
i	گیتوں		str	open	V UV	non wf		105,16	111,58			
i	کبھی		unstr	open	asp V nil	wf		125,41	111,58			
ã	ڈانٹا		str	open	V UV	non wf		154,42	196,23			
u	دُوپیوں		str	open	V UV	non wf		112,54	126,57			
æ	بیٹھک		str	open	V aspUV	non wf		108,92	132,27			
æ	لبیک		str	close	V UV	wf		154,90	132,27			
æ	بیٹھتے		str	close	V aspUV	non wf		130,23	132,27			
ʊ	گُٹھلی		str	close	V aspUV	non wf		61,40	70,39			
	بُھکتو		str	close	asp V UV	non wf		57,57				
ʊ	بُتوں		str	open	V UV	non wf		55,27	70,39	-5,90	-9,65	
	گُھٹا		str	open	aspV UV	non wf		61,18				
ʊ	چابُک		unstr	close	V UV	wf		56,35	70,39			
ə	گَٹَر		str	open	V UV	non wf		77,04	69,59	0,21	0,27	
	گِھٹا		str	open	asp V UV	non wf		76,83				

ə	لاگت	unstr	close	V UV	wf		74,30	69,59		
ə	گھپلا	str	close	asp V UV	non wf		64,07	69,59		
ɪ	پٹھا	str	open	V aspUV	non wf		51,93	56,59		
ɪ	ثابِت	unstr	close	V UV	wf		63,36	56,59		

Appendix G: Minimal Pairs (VOWELS for the factor "Effect of Aspiration (Unvoiced)")

Minimal Pairs for Vowel duration analysis for the factor "Aspiration (Unvoiced)"										
Vowel	Word		Minimal Pairs				Duration in context	Intrinsic duration	Differnce	Percentage increase
ɑ	کاتِب		str	open	UV UV	non wf	107,38	125,44	-13,54	-12,61
	کھا تا		str	open	asp UV UV	non wf	93,84			
ɑ	کاٹنا		str	close	UV UV	non wf	129,04	125,44		
ɑ	ڈاکو		str	open	UV UV	nonwf	118,24	125,44		
ɑ	لوکاٹ		str	close	UV UV	wf	171,09	125,44		
ɑ	تابُوت		unstr	open	UV V	non wf	123,65	125,44		
ɑ	پادری		str	close	UV V	non wf	133,26	125,44		

u	کُوٹا		str	open	UV UV	non wf		92,65	126,57	-10,77	-11,62
	تھُوکا		str	open	asp UV UV	non wf		81,88			
u	ڈاکو		unstr	open	UV Nil	wf		91,82	126,57		
u	کُوٹنا		str	close	UV UV	non wf		102,97	126,57		
u	کرتُوت		str	close	UV UV	wf		138,59	126,57		
i	رکھی		unstr	open	asp UV Nil	wf		84,21	111,58		
	گاتی		unstr	open	UV Nil	wf		101,08			
i	کِیکر		str	open	UV UV	non wf		85,87	111,58		
æ	ٹیکسی		str	close	UV UV	non wf		86,42	132,27		
ã	ٹانکا		str	open	UV UV	non wf		142,63	125,44		
ə	قَتل		str	open	UV UV	non wf		52,92	69,59	8,63	16,31
	پھَٹا		str	open	aspUV UV	non wf		61,56			
ə	تَکڑا		str	close	UV UV	non wf		49,05	69,59	3,93	8,00
	تھپکا		str	close	asp UV UV	non wf		52,97			
ə	تکرَار		unstr	close	UV UV	non wf		48,18	69,59	15,13	31,41
	کھَٹاک		unstr	close	asp UV UV	non wf		63,31			
ə	کتھک		str	close	asp UV UV	wf		74,82	69,59		

	پُهدک	str	close	UV UV	wf	78,44			
ə	پَدید	unstr	open	UV V	non wf	55,96	69,59		
ə	کدو	str	open	UV V	non wf	55,67	69,59		
ʊ	کتُر	str	open	UV UV	non wf	44,69	70,39		
ʊ	ٹُکنا	str	close	UV UV	non wf	44,58	70,39	5,69	12,76
	کُهدتا	str	close	asp UV UV	non wf	50,26			
ɪ	کِتنا	str	close	UV UV	non wf	37,63	56,59	21,50	57,14
	پِهٹکا	str	close	asp UV UV	non wf	59,14			
ɪ	ٹِڈا	str	open	UV V	non wf	58,05	56,59		
	ٹِهگنا	str	close	asp UV V	non wf	59,36			
ɪ	پِهٹا	str	open	asp UV UV	non wf	61,83	56,59		
ɪ	تِتلی	str	close	UV UV	non wf	53,32	56,59		
ɪ	ٹِکیا	unstr	close	UV UV	non wf	46,28	56,59		
ʊ	کُکر	str	open	UV UV	wf	49,80	70,39		
ʊ	کُهدیڑ	unstr	open	asp UV V	non wf	46,92	70,39		
ʊ	کُبڑا	str	close	UV V	non wf	44,23	70,39		

Appendix H: Minimal Pairs (VOWELS for the factor "Position in Word (word final / non word final)"

				Minimal Pairs			Duration in context	Intrinsic duration	Differnce	Percentage increase
Minimal Pairs for Vowel duration analysis for the factor "Position in Word"										
Vowel	**Word**			**Minimal Pairs**						
ɑ	کاٹنا		str	close	UV UV	non wf	129,04	125,44	42,06	32,59
	لوکاٹ		str	close	UV UV	wf	171,09			
ɑ	دَھکا		str	close	UV NIL	wf	123,06	125,44	17,50	14,22
	پھٹاک		unstr	close	UV UV	wf	140,56			
ɑ	تابُوت		unstr	open	UV V	non wf	123,65	125,44	14,97	12,11
	کدہ		unstr	open	UV V	wf	138,62			
ɑ	تاکید		unstr	open	UV UV	non wf	117,10	125,44	1,15	0,98
	ڈاکو		unstr	open	UV UV	wf	118,24			
ɑ	ڈاکا		str	open	V UV	non wf	121,34	125,44		
ɑ	تابُوت		unstr	close	UV V	non wf	123,65	125,44		
ɑ	ڈاکیا		unstr	open	V UV	non wf	114,01	125,44		
ɑ	کھا تا		str	open	asp UV UV	non wf	93,84	125,44		
ɑ	داتری		str	close	V UV	non wf	126,58	125,44		
ɑ	گدھا		unstr	open	asp V nil	wf	130,25	125,44		
ɑ	پادری		str	close	UV V	non	133,26	125,44		

						wf				
i	گیتوں		str	open	V UV	non wf	105,16	111,58		
i	اِڈّی		unstr	open	UV V	wf	90,98	111,58		
i	ترکیب		unstr	close	UV V	wf	126,34	111,58		
i	دیپال		unstr	open	V UV	non wf	88,85	111,58		
i	رکھی		unstr	open	asp UV nil	wf	84,21	111,58		
i	گاتی		unstr	open	UV nil	wf	101,08	111,58		
i	تاکید		str	close	UV V	wf	129,97	111,58		
i	کبھی		unstr	open	asp V nil	wf	125,41	111,58		
ã	ڈانٹا		str	open	V UV	non wf	154,42	196,23		
u	دُوپیوں		str	open	V UV	non wf	112,54	126,57		
u	کدو		unstr	open	UV V	wf	116,68	126,57		
u	مکتُوب		str	close	UV V	wf	136,76	126,57		
u	رکوُد		str	close	UV V	wf	153,48	126,57		
u	کُوٹنا		str	close	UV UV	non wf	102,97	126,57	35,62	34,60
	کرتُوت		str	close	UV UV	wf	138,59			
u	تھُوکا		str	open	aspV UV	non wf	81,88	126,57		

u	تابوت		str	close	V UV	wf		129,72	126,57		
u	ڈاکو		unstr	open	UV nil	wf		91,82	126,57		
æ	بیٹھک		str	open	V aspUV	non wf		108,92	132,27		
æ	ٹیکسسی		str	close	UV UV	non wf		86,42	132,27		
æ	بیٹھتے		str	close	V aspUV	non wf		130,23	132,27		
æ	لبیک		unstr	close	V UV	wf		154,90	132,27		
ʊ	ٹُکنا		str	close	UV UV	non wf		44,58	70,39	5,22	11,71
	کُکر		str	close	UV UV	wf		49,80			
ʊ	دُکان		unstr	open	V UV	non wf		47,66	70,39	8,69	18,23
	چابُک		unstr	close	V UV	wf		56,35			
ʊ	بُتوں		str	open	V UV	non wf		55,27	70,39		
ʊ	کُھدتا		str	close	asp UV UV	non wf		50,26	70,39		
ʊ	گُٹھلی		str	close	V aspUV	non wf		61,40	70,39		
ʊ	پُکار		unstr	open	UV UV	non wf		60,39	70,39		
ʊ	کُبڑا		str	close	UV V	non wf		44,23	70,39		
ʊ	ٹُھکا		unstr	open	asp UV UV	non wf		52,28	70,39		
ə	نکڑَا		str	close	UV UV	non wf		49,05	69,59	29,40	59,94

	پُھدک		str	close	aspUV UV	wf		78,44			
ə	ڈُکیت		unstr	open	V UV	non wf		50,15	69,59	24,15	48,16
	لاگت		unstr	close	V UV	wf		74,30			
ə	تَھِپکا		str	close	asp UV UV	non wf		52,97	69,59	21,85	41,25
	کتَھِک		str	close	asp UV UV	wf		74,82			
ə	پَدید		unstr	close	UV V	non wf		55,96	69,59		
ə	مَکتب		unstr	close	UV V	wf		60,30	69,59		
ə	تکرَار		str	close	UV UV	non wf		48,18	69,59		
ə	برکت		unstr	close	UV UV	wf		61,42	69,59		
ə	گَئَر		str	open	V UV	non wf		77,04	69,59		
ə	تَھکا		unstr	open	asp UV UV	non wf		68,64	69,59		
ə	کپَاٹ		unstr	open	UV UV	non wf		38,31	69,59		
ə	گھَٹُور		str	close	asp V UV	non wf		79,73	69,59		
ə	پَدید		unstr	open	UV V	non wf		55,96	69,59		
ə	کدو		str	close	UV V	non wf		55,67	69,59		
ə	پَھٹا		str	open	asp UV UV	non wf		61,56	69,59		
ɪ	یٹھا		str	open	V aspUV	non wf		51,93	56,59		
ɪ	کِتنا		str	close	UV UV	non wf		37,63	56,59		

ɪ	تِتلی	str	close	UV UV	non wf	53,32			
ɪ	ٹِکیا	str	close	UV UV	non wf	46,28	56,59		
ɪ	یِکھیر	unstr	open	V aspUV	non wf	49,20	56,59	14,16	28,78
	ثاِیت	unstr	close	V UV	wf	63,36			
ɪ	پِھٹا	str	open	asp UV UV	non wf	61,83	56,59		
ɪ	پِھٹکا	str	close	asp UV UV	non wf	59,14	56,59		
ɪ	پِکاس	unstr	open	UV UV	non wf	45,67	56,59		
ɪ	ٹِڈا	str	close	UV V	non wf	58,05	56,59		
ɑ̃	دکھائیں	str	open	asp UV nil	wf	265,04	262,96		

Appendix I: Minimal Pairs (VOWELS for the factor "Syllable Type (Open / Close)"

		Minimal Pairs for Vowel duration analysis for the factor "Syllable type"							
Vowel	**Word**	**Minimal Pairs**				**Duration in context**	**Intrinsic duration**	**Differnce**	**Percentage increase**
ɑ	کاتِب	str	open	UV UV	non wf	107,38	125,44	21,66	20,17
	کاٹنا	str	close	UV UV	non wf	129,04			
ɑ	ڈاکا	str	open	V UV	non wf	121,34	125,44	5,24	4,32
	داتری	str	close	V UV	non wf	126,58			
ɑ	ڈاکو	unstr	open	UV UV	wf	118,24	125,44	22,31	18,87
	پِھٹاک	unstr	close	UV	wf	140,56			

				UV					
ɑ	ٹانکا	str	close	UV UV	non wf	142,63	125,44		
ɑ	تاکید	unstr	open	UV UV	non wf	117,10	125,44		
ɑ	تابُوت	unstr	open	UV V	non wf	123,65	125,44		
ɑ	ڈھاکہ	str	open	V UV	non wf	107,65	125,44		
ɑ	کھا تا	str	open	UV UV	non wf	93,84	125,44		
u	کُوٹا	str	open	UV UV	non wf	92,65	126,57	10,32	11,14
	کُوٹنا	str	close	UV UV	non wf	102,97			
u	دُوپوں	str	open	V UV	non wf	112,54	126,57	-14,03	-12,47
u	تھُو کا	str	open	UV UV	non wf	81,88	126,57	-44,69	-54,58
u	ڈاکو	unstr	open	UV UV	wf	91,82	126,57	-34,76	-37,86
u	تابوت	str	close	V UV	wf	129,72	126,57	3,15	2,42
ã	ڈانٹا	str	open	V UV	non wf	154,42	196,23	-41,81	-27,07
i	گیتوں	str	open	V UV	non wf	105,16	111,58	-6,42	-6,10

i	گاتی	unstr	open	UV UV	wf	101,08	111,58	-10,50	-10,39
i	کِیکر	str	open	UV UV	non wf	85,87	111,58	-25,71	-29,94
i	اِڈّی	unstr	open	V UV	wf	90,98	111,58	-20,60	-22,64
i	ترکیب	unstr	close	UV V	wf	126,34	111,58	14,76	11,68
æ	بیٹھک	str	open	V UV	non wf	108,92	132,27	21,31	19,56
	بیٹھتے	str	close	V UV	non wf	130,23			
æ	ٹیکسی	str	close	UV UV	non wf	86,42	132,27		
ə	قَتل	str	open	UV UV	non wf	52,92	69,59	-3,88	-7,32
	تَکڑا	str	close	UV UV	non wf	49,05			
ə	کپَاٹ	unstr	open	UV UV	non wf	38, 31	69,59	-9,87	-25,76
	تکرَار	unstr	close	UV UV	non wf	48,18			
ə	پَدید	unstr	open	UV V	non wf	55,96	69,59	17,77	31,76
	موکَد	unstr	close	UV V	non wf	73,73			
ə	پَھٹا	str	open	UV UV	non wf	61,56	69,59	-8,59	-13,95
	تَھپکا	str	close	UV UV	non wf	52,97			
ə	گَھٹا	str	open	V UV	non wf	76,83	69,59	-12,76	
	گھِیلا	str	close	V UV	non wf	64,07			

ə	کتَھک	str	close	UV UV	wf		74,82	69,59	5,24	7,00
ə	گھَٹّور	unstr	open	V UV	non wf		79,73	69,59	10,14	12,72
ə	برکت	unstr	close	UV UV	wf		61,42	69,59	-8,16	-13,29
ə	کھَڈّا	str	open	UV V	non wf		58,70	69,59	-10,89	-18,55
ə	مَکتب	unstr	close	UV V	wf		60,30	69,59	-9,28	-15,40
ə	گَٹّر	str	open	V UV	non wf		77,04	69,59	7,45	9,67
I	پھِٹّا	str	open	UV UV	non wf		61,83	56,59	-2,69	-4,35
	پھِٹکا	str	close	UV UV	non wf		59,14			
I	پکاس	unstr	open	UV UV	non wf		45,67	56,59	0,60	1,32
	ٹِکیا	unstr	close	UV UV	non wf		46,28			
I	یِٹّھا	str	open	V UV	non wf		51,93	56,59	-4,67	-8,99
I	کاتِب	unstr	close	UV V	wf		58,62	56,59	2,03	3,46
I	ٹِھگنا	str	close	UV V	non wf		59,36	56,59	2,76	4,66
I	کِتنا	str	close	UV UV	non wf		37,63	56,59	-18,96	-50,39

ɪ	تِتلی	str	close	UV UV	non wf		53,32	56,59	-3,28	-6,15
ʊ	بُتوں	str	open	V UV	non wf		55,27	70,39	6,13	11,09
	گٹُھلی	str	close	V UV	non wf		61,40			
ʊ	کتُر	str	open	UV UV	non wf		44,69	70,39	6,06	13,56
	دُکھنا	str	close	UV UV	non wf		50,75			
ʊ	گُھٹا	str	open	V UV	non wf		61,18	70,39	-3,61	-5,90
	بُھکتو	str	close	V UV	non wf		57,57			
ʊ	کُھدتا	str	close	UV UV	non wf		50,26	70,39	-20,13	-40,04
ʊ	پُکار	unstr	open	UV UV	non wf		60,39	70,39	-10,00	-16,56
ʊ	دُھتکار	unstr	close	V UV	non wf		71,76	70,39	1,37	1,92
ʊ	ٹُھڈا	str	open	UV V	non wf		51,70	70,39	-18,69	-36,15
ʊ	کُھبے	str	open	UV V	non wf		47,23	70,39	-23,16	-49,03
ɑɛ̃	دکھائیں	str	open	UVUV	wf		265,04	262,96	2,09	0,79

Appendix J: Average durations for consonants

Average duration values (in ms) for consonant duration analysis (Each value for each speake an average of 18 duration values)

Word	C	Awais	Nakhat	Kiran	Shanza	Shakeel	Raheel	Average	Std dev
منان	m	93,33	85,64	89,84	93,80	84,83	79,58	87,84	6,64
نسرین	n	80,94	83,55	69,88	78,05	78,87	80,73	78,67	5,20
ٹَسوے	t	27,92	11,16	10,94	11,77	11,47	38,92	18,70	17,70
ڈسچارج	d	15,59	10,58	13,57	8,83	12,28	10,28	11,86	1,18
ٹَھنگیر	tʰ	45,45	70,49	45,09	58,84	43,41	35,73	49,83	6,36
ڈَھنڈار	dʰ	78,33	22,01	20,67	70,89	24,61	48,75	44,21	8,61
سجاد	s	85,47	95,57	90,63	112,65	95,65	85,59	94,26	5,99
زَخار	z	83,22	46,55	32,57	60,14	74,09	54,88	58,58	5,42
چِترال	tʃ	35,22	44,36	39,09	54,41	27,80	45,59	41,08	7,12
جنجال	dʒ	31,15	23,69	21,64	31,14	29,09	22,98	26,61	1,90
رمضان	r	31,38	21,65	20,89	30,27	30,81	28,64	27,27	1,83
للکار	l	58,29	113,39	72,28	82,20	55,72	90,56	78,74	9,92
رمضان	m	113,02	119,17	103,80	115,77	99,02	112,75	110,59	2,53
جَنجال	n	120,97	117,21	106,20	89,89	104,09	100,44	106,47	3,98
پَٹوار	t	52,84	11,78	9,78	24,71	14,44	27,60	23,52	2,93
ایڈریس	d	44,98	21,53	18,49	19,54	20,91	22,53	24,66	5,98
پَٹھوارَ	tʰ	75,06	55,72	43,52	90,77	84,40	34,09	63,93	17,10
گستاخ	s	75,53	63,16	74,94	84,05	73,55	59,61	71,81	6,68
غزوات	z	78,45	63,42	57,60	97,18	83,89	58,61	73,19	3,17
کچنار	tʃ	37,24	94,16	74,04	82,27	57,85	37,04	63,77	1,93
گجرات	dʒ	30,37	44,41	29,71	43,75	38,56	32,47	36,54	5,12
حرکات	r	39,35	38,12	13,29	39,14	45,80	27,47	33,86	7,55
پڑتال	ɽ	138,36	17,26	38,89	30,77	20,16	25,09	45,09	2,40
ملتان	l	79,40	59,60	57,79	66,10	74,17	78,17	69,20	7,47
مسلم	m	91,34	80,22	88,38	112,69	75,44	67,44	85,92	1,50
نرگس	n	66,13	87,56	85,62	86,11	63,10	67,67	76,03	5,19
ٹخنا	t	88,15	8,66	10,36	10,22	11,04	10,51	23,16	5,07
ڈَگمگ	d	114,02	14,36	13,81	8,83	14,04	10,22	29,21	2,43
ٹُھسکی	tʰ	54,76	49,20	51,75	57,96	41,47	30,86	47,67	6,85
سجدے	s	74,55	112,30	100,15	135,28	105,13	85,05	102,08	7,34
زمزم	z	96,10	51,27	34,63	58,22	51,29	50,69	57,03	3,64
چٹنی	tʃ	54,54	53,36	33,00	57,51	24,86	26,90	41,69	22,31
جرنل	dʒ	104,06	30,84	21,07	30,61	36,56	27,04	41,70	2,61
رستم	r	116,10	20,30	21,14	36,04	31,81	36,69	43,68	3,64
لنگڑا	l	85,83	91,21	75,04	97,42	88,94	73,08	85,25	3,00

قمری	m	85,09	103,43	109,93	125,40	85,45	84,15	98,91	3,93
پنجر	n	100,99	92,54	112,13	125,50	106,97	94,67	105,47	4,76
چٹنی	t	22,29	10,17	32,41	13,42	29,11	16,78	20,69	10,19
گَڈوی	d	45,33	25,40	20,08	20,23	25,91	24,82	26,96	3,16
گٹھلی	tʰ	48,61	92,68	91,26	138,45	59,33	75,81	84,36	7,20
گڈھری	dʰ	75,80	21,95	22,73	89,42	20,73	38,79	44,90	19,15
دستک	s	56,19	75,36	61,41	70,30	53,86	56,66	62,30	2,67
غزوہ	z	81,80	58,01	58,16	80,51	77,97	72,11	71,43	2,69
مچلا	tʃ	25,77	105,50	94,46	95,16	52,12	45,69	69,78	6,04
سجدہ	dʒ	34,11	40,93	49,55	55,09	24,80	34,48	39,83	14,89
پردہ	r	84,46	28,60	50,22	48,58	31,88	30,33	45,68	28,74
گڑھا	ɾ	44,32	46,29	41,51	26,44	28,63	32,34	36,59	3,29
چلنا	l	92,45	81,20	129,98	71,42	89,84	110,26	95,85	4,27
مِثال	m	79,95	78,20	74,08	80,41	68,25	61,62	73,75	4,80
نِہال	n	94,12	85,78	68,97	80,53	71,53	71,81	78,79	7,24
ٹَکور	t	13,97	9,24	11,26	11,33	10,88	10,33	11,17	1,48
ڈکار	d	19,84	10,60	10,31	8,84	12,65	11,24	12,25	3,23
ٹُھکان	tʰ	51,45	42,08	36,07	26,02	26,07	24,99	34,45	3,19
ڈِھلان	dʰ	97,65	84,62	68,28	71,44	64,98	61,89	74,81	6,28
سراب	s	103,26	99,99	103,83	129,44	86,26	88,47	101,87	4,66
ذبین	z	86,86	61,97	46,82	53,38	62,16	53,93	60,85	2,79
چٹان	tʃ	16,37	51,78	38,75	57,09	28,23	33,14	37,56	2,85
جاسوس	dʒ	29,67	23,43	18,84	27,95	29,93	28,18	26,33	3,12
رُمال	r	80,59	38,11	22,62	32,25	32,50	37,17	40,54	2,02
لحاظ	l	64,01	74,45	69,62	77,02	66,02	75,48	71,10	4,99
ماتم	m	81,60	91,53	86,54	87,09	77,94	62,57	81,21	3,57
نائک	n	75,91	87,36	91,59	100,11	79,91	53,46	81,39	5,40
ٹوپی	t	10,26	9,52	11,77	9,15	13,63	16,98	11,88	1,52
ڈولی	d	36,94	14,69	18,15	8,92	15,69	15,25	18,27	2,45
ٹھوکر	tʰ	57,69	53,90	46,22	52,20	43,32	41,04	49,06	11,39
ڈھارس	dʰ	80,00	95,97	50,72	85,91	79,50	71,08	77,20	3,73
ساتھی	s	77,75	96,16	100,76	116,83	95,79	78,07	94,23	6,10
زامور	z	50,05	56,37	51,59	62,14	67,74	54,42	57,05	2,32
چاکو	tʃ	30,22	53,55	33,69	40,77	34,04	32,76	37,50	2,28
جامن	dʒ	30,84	33,63	20,45	42,21	36,14	30,13	32,23	1,34
روٹی	r	108,33	39,82	24,11	38,24	33,74	36,84	46,84	27,09
لاغر	l	76,91	72,24	80,17	79,23	85,65	62,68	76,15	4,79

قیمت	m	72,58	91,12	99,59	119,52	91,22	59,70	88,96	23,65
جانب	n	80,57	48,27	73,69	61,22	55,83	42,40	60,33	2,11
سائن	t	13,74	13,54	12,37	28,54	11,25	11,18	15,10	1,89
پنڈت	d	12,57	11,68	12,29	12,44	11,18	10,62	11,80	0,68
بیٹھک	tʰ	32,09	45,74	35,19	52,53	37,81	23,48	37,80	6,19
چوڈھل	dʰ	50,32	52,08	42,48	57,08	31,15	37,26	45,06	15,44
یوسف	s	103,65	92,87	109,65	107,00	122,05	84,05	103,21	2,60
جاذب	z	73,54	53,54	52,80	61,72	51,05	50,57	57,20	4,80
کیچڑ	tʃ	34,11	47,53	34,49	68,87	37,59	46,89	44,91	3,89
پنجم	dʒ	41,08	27,18	19,41	38,37	31,37	27,10	30,75	4,11
حسرت	r	77,15	27,37	22,95	35,12	19,92	29,87	35,40	4,47
کھوڑل	ɾ	33,65	21,37	10,64	23,27	25,25	23,35	22,92	0,80
پالک	l	79,06	61,96	77,99	71,71	69,77	55,61	69,35	5,23
مرحم	m	95,26	105,81	100,80	102,69	86,27	74,85	94,28	2,26
سالن	n	106,41	111,45	101,03	118,18	107,64	81,28	104,33	6,38
جِھرمٹ	t	25,77	21,10	17,49	7,80	14,10	16,65	17,15	1,85
اُمڈ	d		-	-	-	-	-	0,00	0,00
چونسٹھ	tʰ	31,49	30,21	32,15	5,39	21,27	33,02	25,59	3,06
بُھرکس	s	88,92	78,08	93,58	94,45	81,28	68,75	84,18	3,39
مرکز	z	71,06	74,16	73,13	82,91	70,48	52,08	70,64	6,66
لالچ	tʃ	71,48	66,36	69,05	65,89	54,45	44,08	61,88	5,62
بھاوج	dʒ	29,36	73,62	44,65	81,76	56,34	31,97	52,95	4,17
کافر	r	40,02	37,50	34,88	35,21	39,42	31,14	36,36	2,45
گیدڑ	ɾ	41,63	29,37	29,68	24,06	23,41	23,26	28,57	1,31
پاگل	l	66,07	80,97	80,60	101,88	81,36	64,29	79,19	4,98
تمیز	m	73,36	78,22	97,61	89,74	73,01	61,67	78,94	6,41
تابناک	n	54,07	94,39	70,73	103,34	73,29	57,56	75,56	6,45
کھٹاک	t	19,10	14,11	11,03	14,10	16,19	16,79	15,22	2,10
چنڈال	d	30,72	14,61	18,14	14,11	14,44	22,62	19,11	4,79
ٹھٹھول	tʰ	50,44	49,78	47,96	46,50	41,26	40,30	46,04	5,91
سدھال	dʰ	62,68	95,53	49,80	97,28	84,74	64,47	75,75	11,51
تقسیم	s	106,76	136,23	141,00	132,92	129,96	114,97	126,97	3,97
تکذیب	z	77,15	123,64	56,59	89,54	96,38	-	73,88	8,72
پرچون	tʃ	26,08	86,11	54,25	85,94	43,31	32,01	54,62	3,92
انجان	dʒ	26,21	23,69	20,19	33,46	39,51	39,82	30,48	3,16
تقریر	r	52,47	47,57	46,18	41,07	40,06	43,48	45,14	4,04
دھڑام	ɾ	55,97	29,65	21,50	27,77	29,43	47,14	35,24	19,21

چالاک	l	60,47	63,33	64,92	67,00	55,94	53,53	60,86	1,36
گودام	m	70,49	121,09	108,22	91,18	85,05	72,96	91,50	3,48
ایمان	n	81,76	122,98	99,22	103,66	92,43	87,32	97,90	4,13
لوکاٹ	t	17,91	15,05	14,06	5,77	14,88	14,32	13,66	2,37
گھمنڈ	d	25,81	11,67	12,56	8,30	10,31	12,10	13,46	2,60
چکوٹھ	tʰ	48,82	65,75	32,39	43,65	21,74	15,34	37,95	17,43
چاپلوس	s	73,34	91,81	88,60	123,79	84,44	65,90	87,98	7,68
تعویذ	z	57,41	79,64	61,58	98,11	67,20	65,33	71,54	3,32
ڈسپیچ	tʃ	37,87	77,14	53,40	95,03	51,73	26,74	56,98	2,17
سماج	dʒ	30,18	75,36	43,21	70,07	48,40	39,98	51,20	2,64
تدبیر	r	30,80	43,98	46,92	44,43	48,45	45,59	43,36	8,08
کُھدیڑ	ɽ	26,60	29,62	25,85	20,30	29,68	23,01	25,84	1,27
قندیل	l	56,01	101,48	93,65	97,13	90,40	75,42	85,68	12,55
قورمہ	m	46,95	56,98	75,13	91,78	76,86	59,50	67,87	7,29
سامنے	n	68,59	89,41	101,86	78,75	77,33	69,67	80,94	1,49
کانٹا	t	15,03	12,43	11,24	9,77	14,90	13,26	12,77	0,76
گینڈا	d	16,18	18,03	14,03	9,25	11,46	13,81	13,79	0,95
کوٹھا	tʰ	48,47	71,86	53,35	60,31	65,52	48,04	57,92	5,79
مینڈھا	dʰ	38,13	62,96	63,13	28,54	41,26	39,09	45,52	11,62
بھوسا	s	97,51	95,58	97,14	105,94	101,03	67,44	94,11	4,82
غازی	z	77,58	61,88	54,50	77,30	81,06	60,94	68,88	6,63
غنچہ	tʃ	31,49	44,56	40,00	51,19	37,90	30,45	39,26	1,33
پنجہ	dʒ	16,70	25,65	21,88	31,98	32,99	28,18	26,23	2,66
پورا	r	45,84	29,02	33,92	24,35	37,18	32,43	33,79	9,07
کوڑا	ɽ	36,31	28,05	17,78	26,29	23,77	22,22	25,74	4,77
جملہ	l	66,14	51,59	62,02	57,46	63,75	52,91	58,98	4,70
ماں	m	110,04	115,04	95,74	120,49	92,48	81,12	102,48	4,13
نے	n	102,15	123,72	103,95	118,39	86,69	68,36	100,55	4,70
تھا	tʰ	59,15	85,52	69,27	98,45	79,80	77,63	78,31	2,54
ڈھا	dʰ	80,92	107,09	56,27	82,84	86,54	93,69	84,56	2,70
سے	s	100,19	147,24	138,98	140,83	128,32	106,02	126,93	8,36
جو	dʒ	26,33	43,53	27,43	45,87	35,97	35,66	35,80	3,42
رو	r	55,25	38,38	37,18	34,67	45,86	39,76	41,85	8,49
رو	ɽ	48,77	-	-	-	-	-	8,13	0,00
لو	l	87,28	106,27	92,88	112,56	72,56	70,55	90,35	4,73
ٹھیکیدار	tʰ	49,88	41,06	37,61	56,79	49,50	42,48	46,22	4,29
ڈھنڈورا	dʰ	34,02	36,12	18,44	36,97	35,16	33,31	32,34	10,66

سخاوت	s	99,87	84,80	97,72	116,56	81,33	91,56	95,31	4,84
ذبانت	z	47,65	40,61	49,66	47,12	64,30	52,95	50,38	11,45
چراگاه	tʃ	25,26	52,82	37,00	80,33	36,42	41,49	45,55	3,68
جوشاندہ	dʒ	17,58	20,46	38,14	28,14	24,92	31,91	26,86	9,90
رکاوٹ	r	52,20	40,71	21,80	35,11	31,81	36,41	36,34	14,06
لاطینی	l	57,53	66,27	72,72	85,88	67,15	64,06	68,94	11,37
مترادف	m	73,04	68,14	64,98	94,34	73,28	72,47	74,37	2,40
نصرانی	n	56,27	71,93	69,99	74,94	69,98	85,53	71,44	6,18
ٹنڈورا	t	15,69	14,75	15,93	21,57	16,54	22,47	17,83	4,24
ڈپلوما	d	11,41	12,35	12,06	11,13	11,07	11,78	11,63	0,78
ٹھٹھیارا	tʰ	51,66	44,48	39,07	55,58	27,39	46,23	44,07	1,37
ڈھنڈورا	dʰ	13,85	54,20	30,57	46,23	22,55	28,79	32,70	6,97
سرکنڈے	s	83,89	90,59	92,98	108,41	107,51	71,84	92,54	6,96
زنجیرا	z	25,91	40,39	50,43	69,97	63,68	48,19	49,76	5,10
چٹخارا	tʃ	18,00	50,00	35,78	38,26	22,88	25,40	31,72	2,62
جنریٹر	dʒ	22,39	21,57	20,53	41,11	27,81	25,38	26,46	3,15
رضوانی	r	55,30	37,57	11,54	25,06	24,80	31,58	30,97	6,17
لٹریچر	l	74,06	86,08	80,46	70,93	70,41	61,14	73,84	6,56
من	m	106,14	121,23	98,15	120,18	89,56	83,22	103,08	5,68
نب	n	116,52	110,97	97,64	61,81	68,17	68,94	87,34	4,39
ٹک	t	12,07	9,81	10,01	12,92	11,69	12,42	11,49	1,07
ڈر	d	14,20	13,11	11,89	11,03	10,90	14,13	12,54	0,79
ٹھگ	tʰ	45,72	69,00	62,63	73,37	63,06	65,37	63,19	1,67
ڈھل	dʰ	40,71	105,18	75,33	75,70	55,25	69,47	70,27	11,96
سن	s	111,41	142,57	91,68	149,89	126,38	110,18	122,02	25,76
زد	z	53,84	76,24	50,41	55,80	60,09	57,88	59,04	7,26
چت	tʃ	27,81	40,85	40,99	64,54	44,33	44,57	43,85	2,86
جن	dʒ	25,99	47,44	28,71	44,56	38,06	25,91	35,11	2,48
رب	r	43,30	36,62	43,51	40,30	37,83	43,86	40,90	4,37
لت	l	51,29	95,43	94,94	133,01	89,17	62,33	87,70	13,54
پیسنجر	dʒ	16,24	44,78	19,74	28,60	36,41	19,17	27,49	1,79
سنسکرت	r	82,51	23,33	39,94	26,99	26,71	18,81	36,38	2,87
مبادلت	l	62,31	51,65	67,37	73,55	53,59	45,16	58,94	9,94
اسمگلر	m	80,30	39,49	46,60	64,74	64,11	-	49,20	1,41
کنندگی	n	82,19	69,48	66,33	65,77	55,80	90,41	71,66	9,63
ڈسٹمپر	t	10,05	13,93	9,93	15,03	13,86	14,72	12,92	0,76

افسانوی	s	90,59	100,18	120,86	152,71	95,63	103,97	110,66	9,70
گوزبری	z	56,09	59,54	47,32	59,26	60,03	52,09	55,72	2,29
پیچیدگی	tʃ	27,52	70,31	52,36	68,98	51,79	46,25	52,87	5,55
جالندھر	l	37,52	53,52	68,02	59,61	51,94	49,43	53,34	8,59
مار	m	87,25	105,65	95,71	83,63	82,88	71,33	87,74	10,41
ناچ	n	77,35	112,46	87,96	88,15	89,73	62,45	86,35	3,22
ٹال	t	23,39	13,59	10,87	11,35	16,84	17,67	15,62	1,43
ڈاک	d	22,54	15,93	12,63	16,07	12,97	13,96	15,68	2,08
ٹھان	tʰ	61,86	104,36	65,67	89,35	78,86	74,41	79,08	8,51
ڈھال	dʰ	39,14	96,38	36,69	81,86	82,84	78,57	69,25	5,58
جان	dʒ	31,20	37,42	18,38	35,12	32,02	35,66	31,63	4,69
رات	r	93,18	35,74	17,57	45,40	38,20	41,71	45,30	2,13
لاش	l	79,85	77,42	80,08	90,09	87,12	64,74	79,88	5,08
استعمال	m	66,32	71,74	90,82	75,78	61,15	65,91	71,96	4,58
افسوسناک	n	65,06	39,57	45,29	64,73	58,65	46,66	53,33	2,55
پروٹین	t	23,61	25,31	12,37	20,59	13,25	19,60	19,12	3,48
کوریڈار	d	29,93	13,23	12,46	15,23	9,48	13,98	15,72	1,85
پرتشٹھان	tʰ	48,39	85,60	87,16	106,57	26,33	70,67	70,78	15,04
استفسار	s	65,55	104,77	137,83	-	83,92	83,91	79,33	6,02
افرازات	z	72,85	47,08	48,56	61,29	64,88	58,08	58,79	6,37
اتیاچار	tʃ	29,72	53,80	29,11	71,48	35,79	36,00	42,65	3,00
استعجاب	dʒ	30,48	36,99	25,15	32,95	26,22	29,86	30,27	3,14
استخراج	r	40,82	35,38	51,70	31,97	30,68	25,61	36,03	4,49
استقلال	l	65,36	72,02	98,11	81,51	67,23	68,10	75,39	5,79
تمہارا	m	79,12	84,64	75,88	90,05	56,94	54,47	73,52	3,92
پنساری	n	74,90	83,44	91,50	89,51	81,05	89,76	85,03	6,38
پٹواری	t	24,71	10,93	15,89	27,70	16,03	20,53	19,30	3,91
اڈوکیٹ	d	52,23	35,13	14,04	26,48	17,53	16,00	26,90	6,05
اٹھوایا	tʰ		-	-	-	-	-	0,00	0,00
ڈسپنسر	s	63,90	64,31	69,11	77,97	71,93	63,90	68,52	4,87
آزموده	z	69,98	71,94	52,00	55,07	53,58	48,60	58,53	1,17
پچکاری	tʃ	38,78	66,06	63,28	71,44	64,28	72,33	62,70	4,96
گجریلا	dʒ	29,90	55,31	29,83	49,69	29,37	27,41	36,92	8,71
چروابا	r	48,88	56,40	42,66	40,43	39,10	28,60	42,68	2,98
پڑپوتا	ɾ	32,83	29,09	24,97	28,34	21,61	24,58	26,90	3,38
الماری	l	69,84	64,29	64,63	69,38	79,24	69,65	69,50	3,83

دم	m	87,35	134,49	127,35	139,50	113,18	98,52	116,73	7,21
دن	n	109,16	130,47	143,23	116,96	102,82	112,33	119,16	6,76
جٹ	t	19,96	17,31	17,65	13,59	16,86	13,70	16,51	2,98
مڈ	d	27,13	22,32	12,12	21,16	27,11	72,44	30,38	16,38
لِٹھ	tʰ	24,68	44,89	70,01	48,06	28,00	18,46	39,01	7,44
گڈھ	dʰ	24,34	70,34	43,66	45,22	21,79	17,75	37,18	3,81
پس	s	102,27	123,51	99,14	99,91	103,85	73,09	100,29	8,69
جز	z	111,59	73,91	83,86	98,24	72,62	75,72	85,99	4,27
سچ	tʃ	42,47	77,38	59,50	88,76	58,18	34,97	60,21	2,58
جج	dʒ	32,48	80,14	45,45	73,25	55,95	36,27	53,92	4,32
پر	r	49,98	40,74	49,50	57,13	47,90	28,70	45,66	10,27
جڑ	ɽ	44,16	29,05	21,54	31,56	28,04	29,48	30,64	3,04
مل	l	86,08	112,11	119,03	123,99	114,50	104,90	110,10	5,81
ریفرینڈم	m	100,54	104,58	115,48	96,08	108,66	83,09	101,40	5,98
امریکن	n	91,26	84,49	109,72	135,85	96,64	77,14	99,18	7,56
انٹرنٹ	t	20,23	13,75	14,59	11,55	12,43	17,24	14,96	2,29
پلاسٹڈ	d	27,77	15,08	12,53	6,00	11,50	16,33	14,87	1,92
چھیاسٹھ	tʰ	35,86	18,02	21,93	8,85	15,71	15,77	19,36	5,23
دسترس	s	77,16	93,17	85,08	131,02	68,64	51,54	84,43	10,96
متبارز	z	64,77	99,82	72,82	85,57	67,57	59,43	75,00	3,00
لالونچ	tʃ	59,63	101,49	55,26	79,93	69,07	61,17	71,09	8,65
مستخرج	dʒ	36,40	56,71	49,84	87,71	49,04	28,33	51,34	3,32
امرتسر	r	39,15	40,54	40,70	35,72	33,33	65,17	42,43	5,27
چمگادڑ	ɽ	32,43	30,52	31,14	21,26	28,64	23,69	27,94	6,28
آرٹیکل	l	58,84	60,86	92,00	104,98	77,20	73,33	77,87	7,84
پیغمبر	m	111,76	141,97	118,67	127,00	113,96	115,55	121,48	8,42
تابندہ	n	103,44	123,00	109,99	130,03	136,72	108,83	118,67	4,41
جمگھٹوں	t	14,37	11,59	9,67	8,01	12,87	17,24	12,29	0,95
کرنڈوا	d	41,33	32,11	22,17	10,73	25,93	21,06	25,56	2,91
اکسٹھووا ں	tʰ	15,64	56,21	40,64	78,63	70,47	50,82	52,07	3,51
جمناسٹ ک	s	45,58	68,82	61,77	88,84	72,54	55,08	65,44	12,61
پاکیزگی	z	98,46	57,97	43,20	-	70,23	70,49	56,73	19,88
پرموچنی	tʃ	38,04	105,49	74,98	96,12	85,70	57,21	76,26	4,57
اوریجنل	dʒ	39,30	39,44	39,87	88,46	58,41	44,83	51,72	5,55
کارکردہ	r	25,66	32,11	32,24	31,56	35,08	31,04	31,28	3,78

پھلجڑیا	ɾ	40,66	35,70	29,61	27,44	26,63	30,41		31,74	15,50
عبداللہ	l	116,07	90,60	114,59	66,31	119,73	88,93		99,37	2,51
پام	m	82,27	135,72	119,52	115,00	97,74	87,71		106,33	8,03
کان	n	25,18	108,90	113,36	120,64	99,16	86,89		92,35	2,59
چاٹ	t	29,59	10,24	9,59	8,29	11,85	12,01		13,60	2,02
راڈ	d	42,53	10,90	12,27	16,23	26,39	13,63		20,33	12,62
ساٹھ	tʰ	29,20	35,28	41,58	30,43	31,50	11,62		29,93	4,32
مڈھ	dʰ	25,88	72,20	140,56	79,84	28,29	23,65		61,74	14,65
پاس	s	106,56	114,37	94,76	98,92	101,40	68,50		97,42	9,23
تیز	z	39,86	68,70	66,54	79,54	50,93	68,34		62,32	8,55
ناچ	tʃ	47,67	104,57	53,17	77,31	57,47	42,40		63,77	6,50
راج	dʒ	34,67	83,50	44,51	80,82	54,09	38,13		55,95	2,30
تیر	r	55,56	45,62	44,63	45,44	45,97	40,33		46,26	4,76
گاڑ	ɾ	23,54	35,84	31,60	20,79	29,23	23,15		27,36	1,63
تیل	l	73,46	94,92	94,41	108,73	100,78	70,62		90,48	4,84
انتظام	m	78,67	113,65	107,81	98,23	110,01	87,46		99,30	3,10
پاکستان	n	78,49	120,61	110,12	89,84	89,34	94,37		97,13	6,00
ایڈوکیٹ	t	19,15	7,48	12,77	11,19	8,13	13,39		12,02	1,19
اسٹینڈرڈ	d	31,95	9,59	14,13	9,00	20,57	15,54		16,80	5,03
تینتالیس	s	92,76	93,28	99,27	110,70	88,90	72,03		92,82	4,34
دستاویز	z	66,43	66,19	59,79	105,58	64,79	67,96		71,79	3,76
گھچاگھچ	tʃ	32,56	62,37	49,90	67,59	58,41	32,50		50,55	9,17
استخراج	dʒ	28,30	82,71	36,65	73,72	54,80	41,71		52,98	6,57
کاروبار	r	72,19	52,33	82,15	36,29	34,55	24,31		50,30	4,68
قنادیڑ	ɾ	64,92	7,94	23,73	26,07	28,36	37,91		31,49	4,61
ابابیل	l	75,41	103,81	93,11	100,19	93,43	98,08		94,00	4,36

Appendix K: Minimal Pairs (CONSONANTS for the factor "Stress"

Minimal Pairs for Consonant duration analysis for the factor "Stress"									
Cons	Word		Minimal Pairs					Duration in context	Differnce	Percentage increase
m	ماتم		Str	Non wf	Onset	2 syl	Open	79,13	-8,05	-9,24
m	منان		Unstr	Non wf	Onset	2 syl	Close	87,18		

m	قمری	Str	Non wf	Coda	2 syl	Close		94,74	-16,60	-14,91
m	رمضان	UnStr	Non wf	Coda	2 syl	Close		111,33		
m	ماتم	Str	Non wf	Onset	2 Syl	Open		79,13	6,07	8,31
m	مِثال	Unstr	Non wf	Onset	2 syl	Open		73,06		
m	تمیز	Str	wf	Onset	2 syl	Close		74,22	-10,55	-12,44
m	قیمت	Unstr	wf	Onset	2 syl	Close		84,77		
m	گودام	Str	wf	Coda	2 syl	Close		86,16	-5,57	-6,07
m	مرحم	Un str	wf	Coda	2 syl	Close		91,72		
m	اسمگلر	Str	Non wf	Onset	3 syl	Close				
m	مترادف	Un str	Non wf	Onset	3 syl	Close		75,70		
m	استعمال	Str	wf	Onset	3 syl	Close		67,56		
m	خوشامد	Un str	wf	Onset	3 syl	Close				
m	پیغمبر	Str	Non wf	Coda	3 syl	Close		120,67	49,21	68,87
m	تمہارا	Un str	Non wf	Coda	3 syl	Close		71,46		
m	پام	Str	wf	Coda	1 syl	Close		101,28	-10,84	-9,67
m	دم	Un str	wf	Coda	1 syl	Close		112,12		
m	انتظام	Str	wf	Coda	3 syl	Close		96,68	-1,72	-1,75
m	ریفرینڈم	Un str	wf	Coda	3 syl	Close		98,40		
n	نائک	Str	Non wf	Onset	2 syl	Open		77,75	-2,63	-3,28
n	نسرین	Unstr	Non wf	Onset	2 syl	Close		80,38		
n	پنجر	Str	Non wf	Coda	2 syl	Close		103,59	-3,26	-3,05
n	جَنجال	UnStr	Non wf	Coda	2 syl	Close		106,85		

n	ناٹک		Str	Non wf	Onset	2 Syl	Open		77,75	-2,74	-3,40
n	نِہال		Unstr	Non wf	Onset	2 syl	Open		80,49		
n	تابناک		Str	wf	Onset	2 syl	Close		74,05	16,07	27,71
n	جانب		Unstr	wf	Onset	2 syl	Close		57,98		
n	ایمان		Str	wf	Coda	2 syl	Close		95,89	-8,01	-7,71
n	سالن		Un str	wf	Coda	2 syl	Close		103,90		
n	کنندگی		Str	Non wf	Onset	3 syl	Close		73,30	1,76	2,45
n	نصرانی		Un str	Non wf	Onset	3 syl	Close		71,54		
n	افسوسناک		Str	wf	Onset	3 syl	Close		55,24		
n	تمکنت		Un str	wf	Onset	3 syl	Close				
n	تابندہ		Str	Non wf	Coda	3 syl	Close		119,72	36,30	43,51
n	پنساری		Un str	Non wf	Coda	3 syl	Close		83,42		
n	کان		Str	wf	Coda	1 syl	Close		85,20	-28,11	-24,81
n	دن		Un str	wf	Coda	1 syl	Close		113,31		
n	پاکستان		Str	wf	Coda	3 syl	Close		93,34	-2,28	-2,38
n	امریکن		Un str	wf	Coda	3 syl	Close		95,62		
t	ٹوپی		Str	Non wf	Onset	2 Syl	Open		12,19	0,94	8,39
t	ٹَکور		Unstr	Non wf	Onset	2 syl	Open		11,25		
t	کھَٹّاک		Str	wf	Onset	2 syl	Close		16,28	1,23	8,14
t	سائن		Unstr	wf	Onset	2 syl	Close		15,05		
t	لوکاٹ		Str	wf	Coda	2 syl	Close		13,94	-3,44	-19,80
t	جُھرمٹ		Un str	wf	Coda	2 syl	Close		17,38		

t	ڈسٹمپر		Str	Non wf	Onset	3 syl	Close		13,41	-4,80	-26,37
t	ٹنڈورا		Un str	Non wf	Onset	3 syl	Close		18,21		
t	پروٹین		Str	wf	Onset	3 syl	Close		20,20		
t	کنڈکٹر		Un str	wf	Onset	3 syl	Close				
t	جمگھٹوں		Str	Non wf	Coda	3 syl	Close		13,15	-6,90	-34,43
t	پٹواری		Un str	Non wf	Coda	3 syl	Close		20,05		
t	چاٹ		Str	wf	Coda	1 syl	Close		14,97	-1,41	-8,62
t	جٹ		Un str	wf	Coda	1 syl	Close		16,38		
t	ایڈوکیٹ		Str	wf	Coda	3 syl	Close		12,15	-3,15	-20,61
t	انٹرنٹ		Un str	wf	Coda	3 syl	Close		15,31		
t	ٹوپی		Str	Non wf	Onset	2 syl	Open		12,19	-9,03	-42,56
t	تَسوے		Unstr	Non wf	Onset	2 syl	Close		21,22		
t	چٹنی		Str	Non wf	Coda	2 syl	Close		19,08	-8,08	-29,76
t	پَٹوار		UnStr	Non wf	Coda	2 syl	Close		27,16		
d	گڈوی		Str	Non wf	Coda	2 syl	Close		28,95	2,46	9,27
d	ایڈریس		UnStr	Non wf	Coda	2 syl	Close		26,50		
d	ڈولی		Str	Non wf	Onset	2 Syl	Open		19,02	6,06	46,77
d	ڈکار		Unstr	Non wf	Onset	2 syl	Open		12,96		
d	چَنڈال		Str	wf	Onset	2 syl	Close		19,85	8,19	70,26
d	پنڈت		Unstr	wf	Onset	2 syl	Close		11,66		
d	گھمنڈ		Str	wf	Coda	2 syl	Close		14,05		
d	اُمڈ		Un str	wf	Coda	2 syl	Close				

d	پگڈنڈی	Str	Non wf	Onset	3 syl	Close				
d	ڈپلوما	Un str	Non wf	Onset	3 syl	Close		11,53	11,53	
d	کوریڈار	Str	wf	Onset	3 syl	Close		16,61		
d	چمگاڈر	Un str	wf	Onset	3 syl	Close				
d	کرنڈوا	Str	Non wf	Coda	3 syl	Close		26,77	-2,56	-8,73
d	اڈوکیٹ	Un str	Non wf	Coda	3 syl	Close		29,33		
d	راڈ	Str	wf	Coda	1 syl	Close		22,87	-12,53	-35,40
d	مڈ	Un str	wf	Coda	1 syl	Close		35,40		
d	اسٹینڈرڈ	Str	wf	Coda	3 syl	Close		18,22	2,35	14,81
d	پلاسٹڈ	Un str	wf	Coda	3 syl	Close		15,87		
d	ڈولی	Str	Non wf	Onset	2 syl	Open		19,02	7,30	62,35
d	ڈسچارج	Unstr	Non wf	Onset	2 syl	Close		11,71		
th2	گٹھلی	Str	Non wf	Coda	2 syl	Close		79,36	11,93	17,69
th2	پٹھوار	UnStr	Non wf	Coda	2 syl	Close		67,43		
th2	ٹھوکر	Str	Non wf	Onset	2 Syl	Open		49,25	15,12	44,30
th2	ٹھکان	Unstr	Non wf	Onset	2 syl	Open		34,13		
th2	ٹھٹھول	Str	wf	Onset	2 syl	Close		45,38	8,25	22,22
th2	بیٹھک	Unstr	wf	Onset	2 syl	Close		37,13		
th2	چکوٹھ	Str	wf	Coda	2 syl	Close		37,32	12,33	49,32
th2	چونسٹھ	Un str	wf	Coda	2 syl	Close		25,00		
th2	جیٹھنڈا	Str	Non wf	Onset	3 syl	Close				

th2	ٹھٹھیارا		Un str	Non wf	Onset	3 syl	Close		44,52		
th2	پرتشٹھان		Str	wf	Onset	3 syl	Close		64,34		
th2			Un str	wf	Onset	3 syl	Close				
th2	اکسٹھواں		Str	Non wf	Coda	3 syl	Close		52,90		
th2	اٹھوایا		Un str	Non wf	Coda	3 syl	Close				
th2	ساٹھ		Str	wf	Coda	1 syl	Close		27,02	-4,27	-13,66
th2	لٹھ		Un str	wf	Coda	1 syl	Close		31,30		
th2			Str	wf	Coda	3 syl	Close				
th2	چھیاسٹھ		Un str	wf	Coda	3 syl	Close		19,44		
th2	ٹھوکر		Str	Non wf	Onset	2 syl	Open		49,25	0,01	0,02
th2	ٹَھنگیر		Unstr	Non wf	Onset	2 syl	Close		49,24		
dh2	ڈھارس		Str	Non wf	Onset	2 Syl	Open		81,55	5,65	7,45
dh2	ڈِھلان		Unstr	Non wf	Onset	2 syl	Open		75,90		
dh2	سَڈھال		Str	wf	Onset	2 syl	Close		79,22	34,64	77,71
dh2	چوڈھل		Unstr	wf	Onset	2 syl	Close		44,58		
dh2	اوڈھنگا		Str	Non wf	Onset	3 syl	Close				
dh2	ڈھنڈورا		Un str	Non wf	Onset	3 syl	Close		31,23		
dh2	مڈھ		Str	wf	Coda	1 syl	Close		42,63	9,18	27,43
dh2	گڈھ		Un str	wf	Coda	1 syl	Close		33,45		
dh2	ڈھارس		Str	Non wf	Onset	2 syl	Open		81,55	32,36	65,79
dh2	ڈَھنڈار		Unstr	Non wf	Onset	2 syl	Close		49,19		

dh2	گڈھری		Str	Non wf	Coda	2 syl	Close		48,63		
dh2	ٓ		UnStr	Non wf	Coda	2 syl	Close				
s	ساتھی		Str	Non wf	Onset	2 syl	Open		91,41	-2,56	-2,72
s	سجاد		Unstr	Non wf	Onset	2 syl	Close		93,97		
s	دستک		Str	Non wf	Coda	2 syl	Close		61,32	-9,59	-13,52
s	گستاخ		UnStr	Non wf	Coda	2 syl	Close		70,91		
s	ساتھی		Str	Non wf	Onset	2 Syl	Open		91,41	-8,60	-8,60
s	سراب		Unstr	Non wf	Onset	2 syl	Open		100,01		
s	تقسیم		Str	wf	Onset	2 syl	Close		123,01	20,87	20,43
s	یوسف		Unstr	wf	Onset	2 syl	Close		102,14		
s	چاپلوس		Str	wf	Coda	2 syl	Close		85,64	3,78	4,62
s	بُھرکس		Un str	wf	Coda	2 syl	Close		81,85		
s	افسانوی		Str	Non wf	Onset	3 syl	Close		106,63	14,97	16,33
s	سرکنڈے		Un str	Non wf	Onset	3 syl	Close		91,66		
s	استفسار		Str	wf	Onset	3 syl	Close				
s	امرتسر		Un str	wf	Onset	3 syl	Close				
s	جمناسٹک		Str	Non wf	Coda	3 syl	Close		64,77	-3,33	-4,89
s	ڈسپنسر		Un str	Non wf	Coda	3 syl	Close		68,09		
s	پاس		Str	wf	Coda	1 syl	Close		96,98	-2,30	-2,31
s	پس		Un str	wf	Coda	1 syl	Close		99,28		
s	تینتالیس		Str	wf	Coda	3 syl	Close		90,37	9,15	11,27

s	دس‌ترس	Un str	wf	Coda	3 syl	Close		81,22		
z	زامور	Str	Non wf	Onset	2 syl	Open		58,02	-6,91	-10,65
z	زَخار	Unstr	Non wf	Onset	2 syl	Close		64,93		
z	غزوه	Str	Non wf	Coda	2 syl	Close		74,62	-1,25	-1,65
z	غزوات	UnStr	Non wf	Coda	2 syl	Close		75,87		
z	زامور	Str	Non wf	Onset	2 Syl	Open		58,02	-6,30	-9,80
z	ذبین	Unstr	Non wf	Onset	2 syl	Open		64,32		
z	تکذیب	Str	wf	Onset	2 syl	Close				
z	جاذب	Unstr	wf	Onset	2 syl	Close		58,13		
z	تعویذ	Str	wf	Coda	2 syl	Close		71,83	2,63	3,80
z	مرکز	Un str	wf	Coda	2 syl	Close		69,20		
z	گوزبری	Str	Non wf	Onset	3 syl	Close		57,18	8,17	16,66
z	زنجیرا	Un str	Non wf	Onset	3 syl	Close		49,01		
z	افرازات	Str	wf	Onset	3 syl	Close		61,57		
z	متنازع	Un str	wf	Onset	3 syl	Close				
z	پاکیزگی	Str	Non wf	Coda	3 syl	Close				
z	آزموده	Un str	Non wf	Coda	3 syl	Close		59,43		
z	تیز	Str	wf	Coda	1 syl	Close		60,07	-26,39	-30,52
z	جز	Un str	wf	Coda	1 syl	Close		86,45		
z	دستاویز	Str	wf	Coda	3 syl	Close		72,89	-0,62	-0,85
z	متبارز	Un str	wf	Coda	3 syl	Close		73,51	73,51	

ch2	چاکو		Str	Non wf	Onset	2 syl	Open		37,28	-3,32	-8,17
ch2	چِترال		Unstr	Non wf	Onset	2 syl	Close		40,60		
ch2	مچلا		Str	Non wf	Coda	2 syl	Close		60,91	2,14	3,64
ch2	کچنار		UnStr	Non wf	Coda	2 syl	Close		58,77		
ch2	چاکو		Str	Non wf	Onset	2 Syl	Open		37,28	1,86	5,24
ch2	چِٹان		Unstr	Non wf	Onset	2 syl	Open		35,42		
ch2	پرچُون		Str	wf	Onset	2 syl	Close		51,21	5,46	11,93
ch2	کیچِڑ		Unstr	wf	Onset	2 syl	Close		45,75		
ch2	ڈسپیچ		Str	wf	Coda	2 syl	Close		54,54	-5,28	-8,82
ch2	لالچ		Un str	wf	Coda	2 syl	Close		59,82		
ch2	پیچیدگی		Str	Non wf	Onset	3 syl	Close		51,12	21,68	73,64
ch2	چٹخارا		Un str	Non wf	Onset	3 syl	Close		29,44		
ch2	اتیاچار		Str	wf	Onset	3 syl	Close		43,44		
ch2	فرنیچر		Un str	wf	Onset	3 syl	Close				
ch2	پرموچنی		Str	Non wf	Coda	3 syl	Close		73,81	11,92	19,26
ch2	پچکاری		Un str	Non wf	Coda	3 syl	Close		61,89		
ch2	ناچ		Str	wf	Coda	1 syl	Close		63,10	5,27	9,12
ch2	سچ		Un str	wf	Coda	1 syl	Close		57,83		
ch2	گھچاگھچ		Str	wf	Coda	3 syl	Close		49,09	-23,34	-32,22
ch2	لالونچ		Un str	wf	Coda	3 syl	Close		72,43		
dZ	سجدہ		Str	Non wf	Coda	2 syl	Close		36,76	-0,47	-1,26
dZ	گجرات		UnStr	Non	Coda	2 syl	Close		37,23		

			wf							
dZ	جامن	Str	Non wf	Onset	2 Syl	Open		34,22	6,15	21,91
dZ	جاسوس	Unstr	Non wf	Onset	2 syl	Open		28,07		
dZ	انجان	Str	wf	Onset	2 syl	Close		32,98	-0,07	-0,20
dZ	پنجم	Unstr	wf	Onset	2 syl	Close		33,05		
dZ	سماج	Str	wf	Coda	2 syl	Close		50,58	-1,46	-2,81
dZ	بھاوج	Un str	wf	Coda	2 syl	Close		52,05		
dZ	سنجیدگی	Str	Non wf	Onset	3 syl	Close				
dZ	جنریٹر	Un str	Non wf	Onset	3 syl	Close		27,24		
dZ	استعجاب	Str	wf	Onset	3 syl	Close		30,89	2,70	9,58
dZ	پیسنجر	Un str	wf	Onset	3 syl	Close		28,19		
dZ	اوریجنل	Str	Non wf	Coda	3 syl	Close		52,99	16,23	44,15
dZ	گجریلا	Un str	Non wf	Coda	3 syl	Close		36,76		
dZ	راج	Str	wf	Coda	1 syl	Close		55,59	2,31	4,34
dZ	جج	Un str	wf	Coda	1 syl	Close		53,28		
dZ	استخراج	Str	wf	Coda	3 syl	Close		53,81	4,46	9,03
dZ	مستخرج	Un str	wf	Coda	3 syl	Close		49,35		
dZ	جامن	Str	Non wf	Onset	2 syl	Open		34,22	6,59	23,84
dZ	جنجال	Unstr	Non wf	Onset	2 syl	Close		27,63		
r	روٹی	Str	Non wf	Onset	2 syl	Open		52,77	23,93	82,99
r	رمضان	Unstr	Non wf	Onset	2 syl	Close		28,84		

r	پردہ		Str	Non wf	Coda	2 syl	Close		45,46	7,55	19,93
r	حرکات		UnStr	Non wf	Coda	2 syl	Close		37,90		
r	روٹی		Str	Non wf	Onset	2 Syl	Open		52,77	7,65	16,95
r	رُمال		Unstr	Non wf	Onset	2 syl	Open		45,12	45,12	
r	تقریر		Str	wf	Onset	2 syl	Close		45,00	6,37	16,50
r	حسرت		Unstr	wf	Onset	2 syl	Close		38,62		
r	تدبیر		Str	wf	Coda	2 syl	Close		42,48	5,78	15,76
r	کافر		Un str	wf	Coda	2 syl	Close		36,69		
r	چورانوے		Str	Non wf	Onset	3 syl	Close				
r	رضوانی		Un str	Non wf	Onset	3 syl	Close		35,26		
r	استخراج		Str	wf	Onset	3 syl	Close		32,81	-4,03	-10,94
r	سنسکرت		Un str	wf	Onset	3 syl	Close		36,84		
r	کارکردہ		Str	Non wf	Coda	3 syl	Close		31,01	-11,04	-26,25
r	چروابا		Un str	Non wf	Coda	3 syl	Close		42,04		
r	تیر		Str	wf	Coda	1 syl	Close		46,70	2,26	5,08
r	پر		Un str	wf	Coda	1 syl	Close		44,44		
r	کاروبار		Str	wf	Coda	3 syl	Close		43,89	0,60	1,38
r	امرتسر		Un str	wf	Coda	3 syl	Close		43,30		
rr2			Unstr	Non wf	Onset	2 syl	Close				
rr2	گڑھا		Str	Non wf	Coda	2 syl	Close		35,52	-13,29	-27,23
rr2	پڑتال		UnStr	Non wf	Coda	2 syl	Close		48,81		

rr2	دھڑام		Str	wf	Onset	2 syl	Close		39,02	13,30	51,71
rr2	کھوڑل		Unstr	wf	Onset	2 syl	Close		25,72		
rr2	کُھدیڑ		Str	wf	Coda	2 syl	Close		25,94	-2,59	-9,07
rr2	گیدڑ		Un str	wf	Coda	2 syl	Close		28,53		
rr2	پھلجڑیا		Str	Non wf	Coda	3 syl	Close		32,24	5,10	18,81
rr2	پڑپوتا		Un str	Non wf	Coda	3 syl	Close		27,13		
rr2	گاڑ		Str	wf	Coda	1 syl	Close		26,31	-6,39	-19,54
rr2	جڑ		Un str	wf	Coda	1 syl	Close		32,70		
rr2	قنادیڑ		Str	wf	Coda	3 syl	Close		34,82	7,36	26,79
rr2	چمگادڑ		Un str	wf	Coda	3 syl	Close		27,46		
l	لاغر		Str	Non wf	Onset	2 syl	Open		75,30	-2,76	-3,53
l	للکار		Unstr	Non wf	Onset	2 syl	Close		78,06		
l	چلنا		Str	Non wf	Coda	2 syl	Close		90,44	18,00	24,85
l	ملتان		UnStr	Non wf	Coda	2 syl	Close		72,45		
l	لاغر		Str	Non wf	Onset	2 Syl	Open		75,30	4,38	6,18
l	لحاظ		Unstr	Non wf	Onset	2 syl	Open		70,91		
l	چالاک		Str	wf	Onset	2 syl	Close		59,48	-8,23	-12,15
l	پالک		Unstr	wf	Onset	2 syl	Close		67,71		
l	قندیل		Str	wf	Coda	2 syl	Close		82,40	4,87	6,28
l	پاگل		Un str	wf	Coda	2 syl	Close		77,52		
l	جالندھر		Str	Non wf	Onset	3 syl	Close		49,72	-22,14	-30,81

l	لٹریچر		Un str	Non wf	Onset	3 syl	Close		71,86		
l	استقلال		Str	wf	Onset	3 syl	Close		70,19	13,53	23,88
l	مبادلت		Un str	wf	Onset	3 syl	Close		56,66		
l	عبدالله		Str	Non wf	Coda	3 syl	Close		98,31	27,43	38,70
l	الماری		Un str	Non wf	Coda	3 syl	Close		70,88		
l	تیل		Str	wf	Coda	1 syl	Close		88,35	-18,88	-17,61
l	مل		Un str	wf	Coda	1 syl	Close		107,23		
l	ابابیل		Str	wf	Coda	3 syl	Close		93,31	19,15	25,82
l	آرٹیکل		Un str	wf	Coda	3 syl	Close		74,17		

Appendix L: Minimal Pairs (CONSONANTS for the factor "¨Position in Word (Word initial / Word final)"

Minimal Pairs for Consonant duration analysis for the factor "Position in word (Word initial / non word initial)"											
Cons	**Word**		**Minimal Pairs**						**Duration in context**	**Differnce**	**Percentage increase**
m	انتظام		Str	wf	Coda	3 syl	Close		96,68	23,99	24,81
m	پیغمبر		Str	Non wf	Coda	3 syl	Close		120,67		
m	قیمت		Unstr	wf	Onset	2 syl	Close		84,77	2,41	2,84
m	منان		Un str	Non wf	Onset	2 syl	Close		87,18		
⬚											

m	مرحم		Unstr	wf	coda	2 syl	Close		91,72	19,61	21,38
m	رمضان		Unstr	Non wf	Coda	2 syl	Close		111,33		
m	قورمہ		Unstr	wf	Onset	2 syl	Open		65,53	7,53	11,50
m	مِثال		Unstr	Non wf	Onset	2 syl	Open		73,06		
m	مترادف		Unstr	Non wf	Onset	3 syl	Close		75,70		
m	استعمال		Str	wf	Onset	3 syl	Close		67,56		
m	اسمگلر		Str	Non wf	Onset	3 syl	Close				
n	پاکستان		Str	wf	Coda	3 syl	Close		93,34	26,38	28,26
n	تابندہ		Str	Non wf	Coda	3 syl	Close		119,72		
n	جانب		Unstr	wf	Onset	2 syl	Close		57,98	22,40	38,64
n	نسرین		Un str	Non wf	Onset	2 syl	Close		80,38		
n	سالن		Unstr	wf	coda	2 syl	Close		103,90	2,95	2,84
n	جَنجال		Unstr	Non wf	Coda	2 syl	Close		106,85		
n	سامنے		Unstr	wf	Onset	2 syl	Open		75,94	4,55	5,99
n	نِہال		Unstr	Non wf	Onset	2 syl	Open		80,49		
n	نصرانی		Unstr	Non wf	Onset	3 syl	Close		71,54		

n	افسوسناک		Str	wf	Onset	3 syl	Close		55,24	18,05	32,68
n	کنندگی		Str	Non wf	Onset	3 syl	Close		73,30		
t	ایڈوکیٹ		Str	wf	Coda	3 syl	Close		12,15	1,00	8,22
t	جمگھٹوں		Str	Non wf	Coda	3 syl	Close		13,15		
t	سائن		Unstr	wf	Onset	2 syl	Close		15,05	6,17	41,01
t	تَسوے		Un str	Non wf	Onset	2 syl	Close		21,22		
t	جُھرمٹ		Unstr	wf	coda	2 syl	Close		17,38	9,79	56,31
t	پَٹوار		Unstr	Non wf	Coda	2 syl	Close		27,16		
t	کانٹا		Unstr	wf	Onset	2 syl	Open		13,30	-2,05	-15,42
t	ٹَکور		Unstr	Non wf	Onset	2 syl	Open		11,25		
t	ٹنڈورا		Unstr	Non wf	Onset	3 syl	Close		18,21		
t	پروٹین		Str	wf	Onset	3 syl	Close		20,20	-6,79	-33,61
t	ڈسٹمِپر		Str	Non wf	Onset	3 syl	Close		13,41		
d	اسٹینڈرڈ		Str	wf	Coda	3 syl	Close		18,22	8,55	46,91
d	کرنڈوا		Str	Non wf	Coda	3 syl	Close		26,77		

d	پنڈت		Unstr	wf	Onset	2 syl	Close		11,66	0,06	0,48
d	ڈسچارج		Un str	Non wf	Onset	2 syl	Close		11,71		
d	اُمڈ		Unstr	wf	coda	2 syl	Close				
d	ایڈریس		Unstr	Non wf	Coda	2 syl	Close		26,50		
d	گینڈا		Unstr	wf	Onset	2 syl	Open		13,76	-0,80	-5,81
d	ڈکار		Unstr	Non wf	Onset	2 syl	Open		12,96		
d	ڈپلوما		Unstr	Non wf	Onset	3 syl	Close		11,53		
d	کوریڈار		Str	wf	Onset	3 syl	Close		16,61		
th2	بیٹھک		Unstr	wf	Onset	2 syl	Close		37,13	12,11	32,63
th2	ٹھنگیر		Un str	Non wf	Onset	2 syl	Close		49,24		
th2	چونسٹھ		Unstr	wf	coda	2 syl	Close		25,00	42,43	169,76
th2	پٹھوار		Unstr	Non wf	Coda	2 syl	Close		67,43		
th2	کوٹھا		Unstr	wf	Onset	2 syl	Open		58,03	-23,90	-41,19
th2	ٹھکان		Unstr	Non wf	Onset	2 syl	Open		34,13		
th2	ٹھٹھیارا		Unstr	Non wf	Onset	3 syl	Close		44,52		

th2	پرتشسٹھان		Str	wf	Onset	3 syl	Close		64,34		
th2			Str	wf	Coda	3 syl	Close				
th2	اکسٹھواں		Str	Non wf	Coda	3 syl	Close		52,90		
dh2			Str	wf	Coda	3 syl	Close				
dh2			Str	Non wf	Coda	3 syl	Close				
dh2	چوڈھل		Unstr	wf	Onset	2 syl	Close		44,58	4,61	10,35
dh2	دَھنڈار		Un str	Non wf	Onset	2 syl	Close		49,19		
dh2	مینڈھا		Unstr	wf	Onset	2 syl	Open		41,58	34,32	82,55
dh2	ڈِھلان		Unstr	Non wf	Onset	2 syl	Open		75,90		
dh2	ڈھنڈورا		Unstr	Non wf	Onset	3 syl	Close		31,23		
s	تینتالیس		Str	wf	Coda	3 syl	Close		90,37	-25,60	-28,33
s	جمناسٹک		Str	Non wf	Coda	3 syl	Close		64,77		
s	یوسف		Unstr	wf	Onset	2 syl	Close		102,14	-8,17	-8,00
s	سجاد		Un str	Non wf	Onset	2 syl	Close		93,97		
s	بُھرکس		Unstr	wf	coda	2 syl	Close		81,85	-10,94	-13,37
s	گستاخ		Unstr	Non wf	Coda	2 syl	Close		70,91		

s	بھوسا		Unstr	wf	Onset	2 syl	Open		92,69	7,32	7,90
s	سراب		Unstr	Non wf	Onset	2 syl	Open		100,01		
s	سرکنڈے		Unstr	Non wf	Onset	3 syl	Close		91,66		
s	افسانوی		Str	Non wf	Onset	3 syl	Close		106,63		
z	دستاویز		Str	wf	Coda	3 syl	Close		72,89		
z	پاکیزگی		Str	Non wf	Coda	3 syl	Close				
z	جاذب		Unstr	wf	Onset	2 syl	Close		58,13	6,80	11,70
z	زَخار		Un str	Non wf	Onset	2 syl	Close		64,93		
z	مرکز		Unstr	wf	coda	2 syl	Close		69,20	6,66	9,63
z	غزوات		Unstr	Non wf	Coda	2 syl	Close		75,87		
z	غازی		Unstr	wf	Onset	2 syl	Open		71,99	-7,67	-10,65
z	ذبین		Unstr	Non wf	Onset	2 syl	Open		64,32		
z	زنجیرا		Unstr	Non wf	Onset	3 syl	Close		49,01		
z	افرازات		Str	wf	Onset	3 syl	Close		61,57	-4,39	-7,13
z	گوزبری		Str	Non wf	Onset	3 syl	Close		57,18		

ch2	گھچاگھچ		Str	wf	Coda	3 syl	Close		49,09	24,72	50,35
ch2	پرموچنی		Str	Non wf	Coda	3 syl	Close		73,81		
ch2	کیچڑ		Unstr	wf	Onset	2 syl	Close		45,75	-5,16	-11,27
ch2	چترال		Un str	Non wf	Onset	2 syl	Close		40,60		
ch2	لالچ		Unstr	wf	coda	2 syl	Close		59,82	-1,05	-1,76
ch2	کچنار		Unstr	Non wf	Coda	2 syl	Close		58,77		
ch2	غنچہ		Unstr	wf	Onset	2 syl	Open		38,14	-2,72	-7,13
ch2	چٹان		Unstr	Non wf	Onset	2 syl	Open		35,42		
ch2	چٹخارا		Unstr	Non wf	Onset	3 syl	Close		29,44		
ch2	اتیاچار		Str	wf	Onset	3 syl	Close		43,44	7,68	17,68
ch2	پیچیدگی		Str	Non wf	Onset	3 syl	Close		51,12		
dZ	پنجم		Unstr	wf	Onset	2 syl	Close		33,05	-5,42	-16,39
dZ	جنجال		Un str	Non wf	Onset	2 syl	Close		27,63		
dZ	استخراج		Str	wf	Coda	3 syl	Close		53,81	-0,82	-1,52
dZ	اوریجنل		Str	Non wf	Coda	3 syl	Close		52,99		

dZ	بھاوج		Unstr	wf	coda	2 syl	Close		52,05	-14,82	-28,47
dZ	گجرات		Unstr	Non wf	Coda	2 syl	Close		37,23		
dZ	پنجہ		Unstr	wf	Onset	2 syl	Open		26,91	1,16	4,31
dZ	جاسوس		Unstr	Non wf	Onset	2 syl	Open		28,07		
dZ	پیسنجر		Unstr	wf	Onset	3 syl	Close		28,19	-0,95	-3,36
dZ	جنریٹر		Unstr	Non wf	Onset	3 syl	Close		27,24		
dZ	استعجاب		Str	wf	Onset	3 syl	Close		30,89		
dZ	سنجیدگی		Str	Non wf	Onset	3 syl	Close				
r	کاروبار		Str	wf	Coda	3 syl	Close		43,89	-12,89	-29,36
r	کارکردہ		Str	Non wf	Coda	3 syl	Close		31,01		
r	حسرت		Unstr	wf	Onset	2 syl	Close		38,62	-9,79	-25,34
r	رمضان		Un str	Non wf	Onset	2 syl	Close		28,84		
r	کافر		Unstr	wf	coda	2 syl	Close		36,69	1,21	3,30
r	حرکات		Unstr	Non wf	Coda	2 syl	Close		37,90		
r	پورا		Unstr	wf	Onset	2 syl	Open		34,55	10,57	30,59
r	رُمال		Unstr	Non wf	Onset	2 syl	Open		45,12		

r	سنسکرت		Unstr	wf	Onset	3 syl	Close		36,84	-1,58	-4,29
r	رضوانی		Unstr	Non wf	Onset	3 syl	Close		35,26		
r	استخراج		Str	wf	Onset	3 syl	Close		32,81		
r	چورانوے		Str	Non wf	Onset	3 syl	Close				
rr2	قنادیڑ		Str	wf	Coda	3 syl	Close		34,82	-2,59	-7,43
rr2	پھلجڑیا		Str	Non wf	Coda	3 syl	Close		32,24		
rr2	کھوڑل		Unstr	wf	Onset	2 syl	Close		25,72		
rr2			Un str	Non wf	Onset	2 syl	Close				
rr2	گیدڑ		Unstr	wf	coda	2 syl	Close		28,53	20,28	71,09
rr2	پڑتال		Unstr	Non wf	Coda	2 syl	Close		48,81		
rr2	کوڑا		Unstr	wf	Onset	2 syl	Open		27,35		
rr2			Unstr	Non wf	Onset	2 syl	Open				
l	ابابیل		Str	wf	Coda	3 syl	Close		93,31	5,00	5,36
l	عبداللہ		Str	Non wf	Coda	3 syl	Close		98,31		
l	پالک		Unstr	wf	Onset	2 syl	Close		67,71	10,34	15,28
l	للکار		Un str	Non wf	Onset	2 syl	Close		78,06		

Cons	Word							Duration in context	Differnce	Percentage increase
l	پاگل		Unstr	wf	coda	2 syl	Close		77,52	-5,08	-6,55
l	ملتان		Unstr	Non wf	Coda	2 syl	Close		72,45		
l	جملہ		Unstr	wf	Onset	2 syl	Open		58,80	12,12	20,61
l	لحاظ		Unstr	Non wf	Onset	2 syl	Open		70,91		
l	مبادلت		Unstr	wf	Onset	3 syl	Close		56,66	15,20	26,83
l	لٹریچر		Unstr	Non wf	Onset	3 syl	Close		71,86		
l	استقلال		Str	wf	Onset	3 syl	Close		70,19	-20,46	-29,16
l	جالندھر		Str	Non wf	Onset	3 syl	Close		49,72		

Appendix M: Minimal Pairs (CONSONANTS for the factor "Position in syllable (Onset / Coda)"

Minimal Pairs for Consonant duration analysis for the factor "Position in syllable (Onset / Coda)"										
Cons	Word		Minimal Pairs						Duration in context	Differnce	Percentage increase
m	رمضان		Unstr	Non wf	Coda	2 syl	Close		111,33	24,15	27,70
m	منان		Un str	Non wf	Onset	2 syl	Close		87,18		
m	مرحم		Unstr	wf	coda	2 syl	Close		91,72	6,95	8,20
m	قیمت		Unstr	wf	Onset	2 syl	Close		84,77		
m	گودام		Str	wf	Coda	2 syl	Close		86,16	11,93	16,07
m	تمیز								74,22		

m	دم	Unstr	wf	Coda	1 syl	Close		112,12	9,90	9,69
m	من	Unstr	wf	Onset	1 syl	Close		102,22		
m	ریفرینڈم	Unstr	wf	Coda	3 syl	Close		98,40		
m	پیغمبر	Str	Non wf	Coda	3 syl	Close		120,67		
m	اسمگلر	Str	Non wf	Onset	3 syl	Close				
m	پام	Str	wf	Coda	1 syl	Close		101,28	16,07	18,87
m	مار	Str	wf	Onset	1 syl	Close		85,20		
m	انتظام	Str	wf	Coda	3 syl	Close		96,68	29,12	43,10
m	استعمال	Str	wf	Onset	3 syl	Close		67,56		
m	تمہارا	Unstr	Non wf	Coda	3 syl	Close		71,46	-4,24	-5,60
m	مترادف	Unstr	Non wf	Onset	3 syl	Close		75,70		
n	جَنجال	Unstr	Non wf	Coda	2 syl	Close		106,85	26,47	32,92
n	نسرین	Un str	Non wf	Onset	2 syl	Close		80,38		
n	سالن	Unstr	wf	coda	2 syl	Close		103,90	45,92	79,19
n	جانب	Unstr	wf	Onset	2 syl	Close		57,98		
n	ایمان	Str	wf	Coda	2 syl	Close		95,89	21,84	29,50
n	تابناک							74,05		

n	دن	Unstr	wf	Coda	1 syl	Close		113,31	28,15	33,06
n	نب	Unstr	wf	Onset	1 syl	Close		85,16		
n	امریکن	Unstr	wf	Coda	3 syl	Close		95,62		
n	تابندہ	Str	Non wf	Coda	3 syl	Close		119,72	46,43	63,34
n	کنندگی	Str	Non wf	Onset	3 syl	Close		73,30		
n	کان	Str	wf	Coda	1 syl	Close		85,20	0,76	0,89
n	ناچ	Str	wf	Onset	1 syl	Close		84,44		
n	پاکستان	Str	wf	Coda	3 syl	Close		93,34		
n	افسوسناک	Str	wf	Onset	3 syl	Close		55,24		
n	پنساری	Unstr	Non wf	Coda	3 syl	Close		83,42	11,88	16,61
n	نصرانی	Unstr	Non wf	Onset	3 syl	Close		71,54		
t	پَٹوار	Unstr	Non wf	Coda	2 syl	Close		27,16	5,94	27,98
t	ٹَسوے	Un str	Non wf	Onset	2 syl	Close		21,22		
t	جُھرمٹ	Unstr	wf	coda	2 syl	Close		17,38	2,33	15,46
t	ساٹن	Unstr	wf	Onset	2 syl	Close		15,05		
t	لوکاٹ	Str	wf	Coda	2 syl	Close		13,94	-2,34	-14,37
t	کھَٹاک							16,28		
t	جٹ	Unstr	wf	Coda	1 syl	Close		16,38	4,55	38,47

t	ٹک	Unstr	wf	Onset	1 syl	Close		11,83		
t	انٹرنٹ	Unstr	wf	Coda	3 syl	Close		15,31		
t	جمگھٹوں	Str	Non wf	Coda	3 syl	Close		13,15	-0,26	-1,93
t	ڈسٹمپر	Str	Non wf	Onset	3 syl	Close		13,41		
t	چاٹ	Str	wf	Coda	1 syl	Close		14,97	-2,05	-12,07
t	ٹال	Str	wf	Onset	1 syl	Close		17,02		
t	ایڈوکیٹ	Str	wf	Coda	3 syl	Close		12,15	-8,04	-39,83
t	پروٹین	Str	wf	Onset	3 syl	Close		20,20		
t	پٹواری	Unstr	Non wf	Coda	3 syl	Close		20,05	1,84	10,13
t	ٹنڈورا	Unstr	Non wf	Onset	3 syl	Close		18,21		
d	ایڈریس	Unstr	Non wf	Coda	2 syl	Close		26,50	14,78	126,18
d	ڈسچارج	Unstr	Non wf	Onset	2 syl	Close		11,71		
d	اُمڈ	Unstr	wf	coda	2 syl	Close				
d	پنڈت	Unstr	wf	Onset	2 syl	Close		11,66		
d	گھمنڈ	Str	wf	Coda	2 syl	Close		14,05	-5,80	-29,24
d	چَنڈال							19,85		
d	مڈ	Unstr	wf	Coda	1 syl	Close		35,40	22,66	177,81
d	ڈر	Unstr	wf	Onset	1 syl	Close		12,74		

d	پلاسٹڈ	Unstr	wf	Coda	3 syl	Close		15,87		
d	کرنڈوا	Str	Non wf	Coda	3 syl	Close		26,77		
d	راڈ	Str	wf	Coda	1 syl	Close		22,87	6,54	40,08
d	ڈاک	Str	wf	Onset	1 syl	Close		16,32		
d	اسٹینڈرڈ	Str	wf	Coda	3 syl	Close		18,22	1,61	9,71
d	کوریڈار	Str	wf	Onset	3 syl	Close		16,61		
d	اڈوکیٹ	Unstr	Non wf	Coda	3 syl	Close		29,33	17,80	154,45
d	ڈپلوما	Unstr	Non wf	Onset	3 syl	Close		11,53		
th2	پَٹھوار	Unstr	Non wf	Coda	2 syl	Close		67,43	18,19	36,93
th2	ٹَھنگیر	Unstr	Non wf	Onset	2 syl	Close		49,24		
th2	چونسٹھ	Unstr	wf	coda	2 syl	Close		25,00	-12,13	-32,68
th2	بیٹھک	Unstr	wf	Onset	2 syl	Close		37,13		
th2	چکوٹھ	Str	wf	Coda	2 syl	Close		37,32	-8,05	-17,75
th2	ٹھَٹھول							45,38		
th2	لٹھ	Unstr	wf	Coda	1 syl	Close		31,30	-31,13	-49,87
th2	ٹھگ	Unstr	wf	Onset	1 syl	Close		62,43		
th2	چھیاسٹھ	Unstr	wf	Coda	3 syl	Close		19,44		

th2	اکسٹھواں		Str	Non wf	Coda	3 syl	Close		52,90		
th2	ساٹھ		Str	wf	Coda	1 syl	Close		27,02	-53,07	-66,26
th2	ٹھان		Str	wf	Onset	1 syl	Close		80,09		
th2	پرتشٹھان		Str	wf	Onset	3 syl	Close		64,34		
th2	ٹھٹھیارا		Unstr	Non wf	Onset	3 syl	Close		44,52		
dh2	ؐ		Unstr	Non wf	Coda	2 syl	Close				
dh2	ڈَھنڈار		Un str	Non wf	Onset	2 syl	Close		49,19		
dh2			Unstr	wf	coda	2 syl	Close				
dh2	چوڈھل		Unstr	wf	Onset	2 syl	Close		44,58		
dh2			Str	wf	Coda	2 syl	Close				
dh2	سدَّھال								79,22		
dh2	گڈُھ		Unstr	wf	Coda	1 syl	Close		33,45	-33,45	-50,00
dh2	ڈُھل		Unstr	wf	Onset	1 syl	Close		66,91		
dh2			Unstr	wf	Coda	3 syl	Close				
dh2	مڈُھ		Str	wf	Coda	1 syl	Close		42,63	-31,64	-42,60
dh2	ڈُھال		Str	wf	Onset	1 syl	Close		74,27		

dh2	ڈھنڈورا		Unstr	Non wf	Onset	3 syl	Close		31,23		
s	گستاخ		Unstr	Non wf	Coda	2 syl	Close		70,91	-23,06	-24,54
s	سجاد		Un str	Non wf	Onset	2 syl	Close		93,97		
s	بُھرکس		Unstr	wf	coda	2 syl	Close		81,85	-20,29	-19,86
s	یوسف		Unstr	wf	Onset	2 syl	Close		102,14		
s	چاپلوس		Str	wf	Coda	2 syl	Close		85,64	-37,37	-30,38
s	تقسیم								123,01		
s	پس		Unstr	wf	Coda	1 syl	Close		99,28	-26,79	-21,25
s	سن		Unstr	wf	Onset	1 syl	Close		126,07		
s	دسترس		Unstr	wf	Coda	3 syl	Close		81,22		
s	جمناسٹک		Str	Non wf	Coda	3 syl	Close		64,77	-41,87	-39,26
s	افسانوی		Str	Non wf	Onset	3 syl	Close		106,63		
s	پاس		Str	wf	Coda	1 syl	Close		96,98		
s	تینتالیس		Str	wf	Coda	3 syl	Close		90,37		
s	استفسار		Str	wf	Onset	3 syl	Close				
s	ڈسپنسر		Unstr	Non wf	Coda	3 syl	Close		68,09	-23,57	-25,71
s	سرکنڈے		Unstr	Non wf	Onset	3 syl	Close		91,66		

z	غزوات	Unstr	Non wf	Coda	2 syl	Close		75,87	10,93	16,84
z	زَخار	Un str	Non wf	Onset	2 syl	Close		64,93		
z	مرکز	Unstr	wf	coda	2 syl	Close		69,20	11,07	19,04
z	جاذب	Unstr	wf	Onset	2 syl	Close		58,13		
z	تعویذ	Str	wf	Coda	2 syl	Close		71,83		
z	تکذیب									
z	جز	Unstr	wf	Coda	1 syl	Close		86,45	26,27	43,65
z	زد	Unstr	wf	Onset	1 syl	Close		60,19		
z	متبارز	Unstr	wf	Coda	3 syl	Close		73,51		
z	پاکیزگی	Str	Non wf	Coda	3 syl	Close				
z	گوزبری	Str	Non wf	Onset	3 syl	Close		57,18		
z	تیز	Str	wf	Coda	1 syl	Close		60,07		
z	دسـتاویز	Str	wf	Coda	3 syl	Close		72,89	11,32	18,38
z	افرازات	Str	wf	Onset	3 syl	Close		61,57		
z	آزموده	Unstr	Non wf	Coda	3 syl	Close		59,43	10,41	21,25
z	زنجیرا	Unstr	Non wf	Onset	3 syl	Close		49,01		

ch2	کچنار		Unstr	Non wf	Coda	2 syl	Close		58,77	18,17	44,76
ch2	چِترال		Un str	Non wf	Onset	2 syl	Close		40,60		
ch2	لالچ		Unstr	wf	coda	2 syl	Close		59,82	14,07	30,75
ch2	کیچڑ		Unstr	wf	Onset	2 syl	Close		45,75		
ch2	ڈسپیچ		Str	wf	Coda	2 syl	Close		54,54	3,33	6,51
ch2	پرچُون								51,21		
ch2	سچ		Unstr	wf	Coda	1 syl	Close		57,83	14,33	32,93
ch2	چت		Unstr	wf	Onset	1 syl	Close		43,50		
ch2	لالونچ		Unstr	wf	Coda	3 syl	Close		72,43		
ch2	پرموچنی		Str	Non wf	Coda	3 syl	Close		73,81	22,70	44,40
ch2	پیچیدگی		Str	Non wf	Onset	3 syl	Close		51,12		
ch2	ناچ		Str	wf	Coda	1 syl	Close		63,10	48,13	321,60
ch2	چاٹ		Str	wf	Onset	1 syl	Close		14,97		
ch2	گھچاگھچ		Str	wf	Coda	3 syl	Close		49,09	5,66	13,03
ch2	اتیاچار		Str	wf	Onset	3 syl	Close		43,44		
ch2	پچکاری		Unstr	Non wf	Coda	3 syl	Close		61,89	32,45	110,24
ch2	چٹخارا		Unstr	Non wf	Onset	3 syl	Close		29,44		
dZ	گجرات		Unstr	Non wf	Coda	2 syl	Close		37,23	9,59	34,72

dZ	جنجال		Un str	Non wf	Onset	2 syl	Close		27,63		
dZ	بھاوج		Unstr	wf	coda	2 syl	Close		52,05	19,00	57,49
dZ	پنجم		Unstr	wf	Onset	2 syl	Close		33,05		
dZ	سماج		Str	wf	Coda	2 syl	Close		50,58	17,60	53,38
dZ	انجان								32,98		
dZ	جج		Unstr	wf	Coda	1 syl	Close		53,28	17,95	50,82
dZ	جن		Unstr	wf	Onset	1 syl	Close		35,32		
dZ	مستخرج		Unstr	wf	Coda	3 syl	Close		49,35	21,16	75,06
dZ	پیسنجر		Unstr	wf	Onset	3 syl	Close		28,19		
dZ	اوریجنل		Str	Non wf	Coda	3 syl	Close		52,99		
dZ	راج		Str	wf	Coda	1 syl	Close		55,59	21,52	63,19
dZ	جان		Str	wf	Onset	1 syl	Close		34,06		
dZ	استخراج		Str	wf	Coda	3 syl	Close		53,81	22,92	74,18
dZ	استعجاب		Str	wf	Onset	3 syl	Close		30,89		
dZ	گجریلا		Unstr	Non wf	Coda	3 syl	Close		36,76	9,52	34,94
dZ	جنریٹر		Unstr	Non wf	Onset	3 syl	Close		27,24	27,24	
r	حرکات		Unstr	Non wf	Coda	2 syl	Close		37,90	9,07	31,44
r	رمضان		Un str	Non wf	Onset	2 syl	Close		28,84		

r	کافر	Unstr	wf	coda	2 syl	Close		36,69	-1,93	-5,00
r	حسرت	Unstr	wf	Onset	2 syl	Close		38,62		
r	تدبیر	Str	wf	Coda	2 syl	Close		42,48	-2,52	-5,60
r	تقریر							45,00		
r	پر	Unstr	wf	Coda	1 syl	Close		44,44	3,85	9,47
r	رب	Unstr	wf	Onset	1 syl	Close		40,60		
r	امرتسر	Unstr	wf	Coda	3 syl	Close		43,30	6,46	17,54
r	سنسکرت	Unstr	wf	Onset	3 syl	Close		36,84		
r	کارکرده	Str	Non wf	Coda	3 syl	Close		31,01		
r	تیر	Str	wf	Coda	1 syl	Close		46,70	-5,29	-10,17
r	رات	Str	wf	Onset	1 syl	Close		51,99		
r	کاروبار	Str	wf	Coda	3 syl	Close		43,89	11,09	33,80
r	استخراج	Str	wf	Onset	3 syl	Close		32,81		
r	چروابا	Unstr	Non wf	Coda	3 syl	Close		42,04	6,79	19,25
r	رضوانی	Unstr	Non wf	Onset	3 syl	Close		35,26		
rr2	پڑتال	Unstr	Non wf	Coda	2 syl	Close		48,81		
rr2		Un str	Non wf	Onset	2 syl	Close				

rr2	گیدڑ		Unstr	wf	coda	2 syl	Close		28,53	2,81	10,91
rr2	کھوڑل		Unstr	wf	Onset	2 syl	Close		25,72		
rr2	کُھدیڑ		Str	wf	Coda	2 syl	Close		25,94	-13,08	-33,52
rr2	دھڑام								39,02		
rr2	جڑ		Unstr	wf	Coda	1 syl	Close		32,70		
rr2	چمگادڑ		Unstr	wf	Coda	3 syl	Close		27,46		
rr2			Unstr	wf	Onset	3 syl	Close				
rr2	پھلجڑیا		Str	Non wf	Coda	3 syl	Close		32,24		
rr2	گاڑ		Str	wf	Coda	1 syl	Close		26,31		
rr2	قنادیڑ		Str	wf	Coda	3 syl	Close		34,82		
rr2			Str	wf	Onset	3 syl	Close				
rr2	پڑپوتا		Unstr	Non wf	Coda	3 syl	Close		27,13		
rr2			Unstr	Non wf	Onset	3 syl	Close				
l	ملتان		Unstr	Non wf	Coda	2 syl	Close		72,45	-5,61	-7,19
l	للکار		Un str	Non wf	Onset	2 syl	Close		78,06		
l	پاگل		Unstr	wf	coda	2 syl	Close		77,52	9,81	14,49
l	پالک		Unstr	wf	Onset	2 syl	Close		67,71		

l	قندیل	Str	wf	Coda	2 syl	Close		82,40	22,91	38,52
l	چالاک							59,48		
l	مل	Unstr	wf	Coda	1 syl	Close		107,23	24,09	28,98
l	لت	Unstr	wf	Onset	1 syl	Close		83,14		
l	آرٹیکل	Unstr	wf	Coda	3 syl	Close		74,17	17,51	30,90
l	مبادلت	Unstr	wf	Onset	3 syl	Close		56,66		
l	عبداللہ	Str	Non wf	Coda	3 syl	Close		98,31	48,59	97,73
l	جالندھر	Str	Non wf	Onset	3 syl	Close		49,72		
l	تیل	Str	wf	Coda	1 syl	Close		88,35	8,94	11,26
l	لاش	Str	wf	Onset	1 syl	Close		79,41		
l	ابابیل	Str	wf	Coda	3 syl	Close		93,31	23,13	32,95
l	استقلال	Str	wf	Onset	3 syl	Close		70,19		
l	الماری	Unstr	Non wf	Coda	3 syl	Close		70,88	-0,97	-1,36
l	لٹریچر	Unstr	Non wf	Onset	3 syl	Close		71,86		

Appendix N: Minimal Pairs (CONSONANTS for the factor "Syllable Type (Open / Close)"

Minimal Pairs for Consonant duration analysis for the factor "Syllable type (Open / Close)"									
Cons	Word		Minimal Pairs					Duration in context	Differnce	Percentage increase

m	مترادف		Unstr	Non wf	Onset	3 syl	Close	75,70		
m	مِثال		Unstr	Non wf	Onset	2 syl	Open	73,06	14,12	19,33
m	منان		Unstr	Non wf	Onset	2 syl	Close	87,18		
m	قورمہ		Unstr	wf	Onset	2 syl	Open	65,53	19,25	29,37
m	قیمت		Unstr	wf	Onset	2 syl	Close	84,77		
n	نصرانی		Unstr	Non wf	Onset	3 syl	Close	71,54		
n	نِہال		Unstr	Non wf	Onset	2 syl	Open	80,49	-0,10	-0,13
n	نسرین		Unstr	Non wf	Onset	2 syl	Close	80,38		
n	سامنے		Unstr	wf	Onset	2 syl	Open	75,94	-17,96	-23,64
n	جانب		Unstr	wf	Onset	2 syl	Close	57,98		
t	ٹنڈورا		Unstr	Non wf	Onset	3 syl	Close	18,21		
t	ٹَکور		Unstr	Non wf	Onset	2 syl	Open	11,25	9,98	88,69
t	ٹَسوے		Unstr	Non wf	Onset	2 syl	Close	21,22		
t	کانٹا		Unstr	wf	Onset	2 syl	Open	13,30	1,75	13,18
t	سائن		Unstr	wf	Onset	2 syl	Close	15,05		
d	ڈپلوما		Unstr	Non wf	Onset	3 syl	Close	11,53		
d	ڈکار		Unstr	Non wf	Onset	2 syl	Open	12,96	-1,24	-9,60

d	ڈسچارج		Unstr	Non wf	Onset	2 syl	Close		11,71		
d	گینڈا		Unstr	wf	Onset	2 syl	Open		13,76	-2,10	-15,26
d	پنڈت		Unstr	wf	Onset	2 syl	Close		11,66		
th2	ٹھیکیدار		Unstr	Non wf	Onset	3 syl	Open		47,83	-3,32	-6,94
th2	ٹھٹھیارا		Unstr	Non wf	Onset	3 syl	Close		44,52		
th2	ٹُھکان		Unstr	Non wf	Onset	2 syl	Open		34,13	15,11	44,27
th2	ٹَھنگیر		Unstr	Non wf	Onset	2 syl	Close		49,24		
th2	کوٹھا		Unstr	wf	Onset	2 syl	Open		58,03	-20,91	-36,02
th2	بیٹھک		Unstr	wf	Onset	2 syl	Close		37,13		
dh2	ڈھنڈورا		Unstr	Non wf	Onset	3 syl	Open		34,96	-3,73	-10,67
dh2	ڈھنڈورا		Unstr	Non wf	Onset	3 syl	Close		31,23		
dh2	ڈِھلان		Unstr	Non wf	Onset	2 syl	Open		75,90	-26,71	-35,19
dh2	ڈَھنڈار		Unstr	Non wf	Onset	2 syl	Close		49,19		
dh2	مینڈھا		Unstr	wf	Onset	2 syl	Open		41,58	3,00	7,21
dh2	چوڈھل		Unstr	wf	Onset	2 syl	Close		44,58		
s	سخاوت		Unstr	Non wf	Onset	3 syl	Open		94,17	-2,51	-2,66
s	سرکنڈے		Unstr	Non wf	Onset	3 syl	Close		91,66		
s	سراب		Unstr	Non wf	Onset	2 syl	Open		100,01	-6,04	-6,04
s	سجاد		Unstr	Non	Onset	2	Close		93,97		

			wf		syl					
s	بھوسا		Unstr	wf	Onset	2 syl	Open	92,69	9,45	10,19
s	یوسف		Unstr	wf	Onset	2 syl	Close	102,14		
z	ذبانت		Unstr	Non wf	Onset	3 syl	Open	51,26	-2,25	-4,39
z	زنجیرا		Unstr	Non wf	Onset	3 syl	Close	49,01		
z	ذبین		Unstr	Non wf	Onset	2 syl	Open	64,32	0,61	0,95
z	زَخار		Unstr	Non wf	Onset	2 syl	Close	64,93		
z	غازی		Unstr	wf	Onset	2 syl	Open	71,99	-13,86	-19,25
z	جاذب		Unstr	wf	Onset	2 syl	Close	58,13		
ch2	چراگاہ		Unstr	Non wf	Onset	3 syl	Open	45,12	-15,68	-34,75
ch2	چٹخارا		Unstr	Non wf	Onset	3 syl	Close	29,44		
ch2	چٹان		Unstr	Non wf	Onset	2 syl	Open	35,42	5,17	14,61
ch2	چِترال		Unstr	Non wf	Onset	2 syl	Close	40,60		
ch2	غنچہ		Unstr	wf	Onset	2 syl	Open	38,14	7,61	19,95
ch2	کیچڑ		Unstr	wf	Onset	2 syl	Close	45,75		
dZ	جنریٹر		Unstr	Non wf	Onset	3 syl	Close	27,24	-2,61	-9,57
dZ	جوشاندہ		Unstr	Non wf	Onset	3 syl	Open	24,63		
dZ	جاسوس		Unstr	Non wf	Onset	2 syl	Open	28,07	-0,44	-1,56
dZ	جنجال		Unstr	Non wf	Onset	2 syl	Close	27,63		

dZ	پنجم		Unstr	wf	Onset	2 syl	Open	26,91	6,14	22,81
dZ	پنجم		Unstr	wf	Onset	2 syl	Close	33,05		
r	رضوانی		Unstr	Non wf	Onset	3 syl	Close	35,26	4,14	11,74
r	رکاوٹ		Unstr	Non wf	Onset	3 syl	Open	39,40		
r	رُمال		Unstr	Non wf	Onset	2 syl	Open	45,12	-16,28	-36,09
r	رمضان		Unstr	Non wf	Onset	2 syl	Close	28,84		
r	پورا		Unstr	wf	Onset	2 syl	Open	34,55	4,08	11,80
r	حسرت		Unstr	wf	Onset	2 syl	Close	38,62		
rr2	کوڑا		Unstr	wf	Onset	2 syl	Open	27,35	-1,63	-5,95
rr2	کھوڑل		Unstr	wf	Onset	2 syl	Close	25,72		
l	لاطینی		Unstr	Non wf	Onset	3 syl	Open	67,30	4,56	6,77
l	لٹریچر		Unstr	Non wf	Onset	3 syl	Close	71,86		
l	لحاظ		Unstr	Non wf	Onset	2 syl	Open	70,91	7,14	10,07
l	للکار		Unstr	Non wf	Onset	2 syl	Close	78,06		
l	جملہ		Unstr	wf	Onset	2 syl	Open	58,80	8,91	15,16
l	پالک		Unstr	wf	Onset	2 syl	Close	67,71		

Appendix O: Minimal Pairs (CONSONANTS for the factor "Number of syllables (1, 2, 3)"

	Minimal Pairs for Consonant duration analysis for the factor "Number of syllables (1, 2, 3)"									Duration in context	Differnce	% increase
	Cons	**Word**			**Minimal Pairs**					**Duration in context**	**Differnce**	**% increase**
1 vs 2 syllables												
	m	ماں		Unstr	Non wf	Onset	1 syl	Open		102,28	29,22	40,00
	m	مِثال		Unstr	Non wf	Onset	2 syl	Open		73,06		
	m	من		Unstr	wf	Onset	1 syl	Close		102,22	17,44	20,58
	m	قیمت		Unstr	wf	Onset	2 syl	Close		84,77		
	m	دم		Unstr	wf	Coda	1 syl	Close		112,12	20,40	22,24
	m	مرحم		Unstr	wf	coda	2 syl	Close		91,72		
	m	مار		Str	wf	Onset	1 syl	Close		85,20	10,98	14,79
	m	تمیز		Str	wf	Onset	2 syl	Close		74,22		
	m	پام		Str	wf	Coda	1 syl	Close		101,28	15,12	17,55
	m	گودام		Str	wf	Coda	2 syl	Close		86,16		
2 vs 3 syllables												
	m	پام		Str	wf	Coda	1 syl	Close		101,28	4,60	4,76
	m	انتظام		Str	wf	Coda	3 syl	Close		96,68		

	m	مار		Str	wf	Onset	1 syl	Close	85,20	17,64	26,11
	m	استعمال		Str	wf	Onset	3 syl	Close	67,56		
	m	دم		Unstr	wf	Coda	1 syl	Close	112,12	13,72	13,95
	m	ریفرینڈم		Unstr	wf	Coda	3 syl	Close	98,40		
	m	پام		Str	wf	Coda	1 syl	Close	101,28	4,60	4,76
	m	انتظام		Str	wf	Coda	3 syl	Close	96,68		
1 vs 3 syllables											
	m	منان		Unstr	Non wf	Onset	2 syl	Close	87,18	11,48	15,17
	m	مترادف		Unstr	Non wf	Onset	3 syl	Close	75,70		
	m	رمضان		Unstr	Non wf	Coda	2 syl	Close	111,33	39,88	55,80
	m	تمہارا		Unstr	Non wf	Coda	3 syl	Close	71,46		
	m	قمری		Str	Non wf	Coda	2 syl	Close	94,74	-25,93	-21,49
	m	پیغمبر		Str	Non wf	Coda	3 syl	Close	120,67		
	m	مرحم		Unstr	wf	coda	2 syl	Close	91,72	-6,67	-6,78
	m	ریفرینڈم		Unstr	wf	Coda	3 syl	Close	98,40		
	m	تمیز		Str	wf	Onset	2 syl	Close	74,22	6,66	9,86
	m	استعمال		Str	wf	Onset	3 syl	Close	67,56		
	m	گودام		Str	wf	Coda	2 syl	Close	86,16	-10,52	-10,88

	m	انتظام		Str	wf	Coda	3 syl	Close	96,68		
	m	مِثال		Unstr	Non wf	Onset	2 syl	Open	73,06		
	m	قیمت		Unstr	wf	Onset	2 syl	Close	84,77		
	m	ماں		Unstr	Non wf	Onset	1 syl	Open	102,28		
	m	من		Unstr	wf	Onset	1 syl	Close	102,22		
1 vs 2 syllables											
	n	ناچ		Str	wf	Onset	1 syl	Close	84,44	10,39	14,04
	n	تابناک		Str	wf	Onset	2 syl	Close	74,05		
	n	نب		Unstr	wf	Onset	1 syl	Close	85,16	27,18	46,87
	n	جانب		Unstr	wf	Onset	2 syl	Close	57,98		
	n	دن		Unstr	wf	Coda	1 syl	Close	113,31	9,41	9,06
	n	سالن		Unstr	wf	coda	2 syl	Close	103,90		
	n	نِے		Unstr	Non wf	Onset	1 syl	Open	97,51	17,02	21,15
	n	نِہال		Unstr	Non wf	Onset	2 syl	Open	80,49		
	n	کان		Str	wf	Coda	1 syl	Close	85,20	-10,69	-11,15
	n	ایمان		Str	wf	Coda	2 syl	Close	95,89		

2 vs 3 syllables										
	n	سالن	Unstr	wf	coda	2 syl	Close	103,90	8,28	8,66
	n	امریکن	Unstr	wf	Coda	3 syl	Close	95,62		
	n	پنجر	Str	Non wf	Coda	2 syl	Close	103,59	-16,13	-13,48
	n	تابنده	Str	Non wf	Coda	3 syl	Close	119,72		
	n	نسرین	Unstr	Non wf	Onset	2 syl	Close	80,38	8,84	12,36
	n	نصرانی	Unstr	Non wf	Onset	3 syl	Close	71,54		
	n	ایمان	Str	wf	Coda	2 syl	Close	95,89	2,55	2,73
	n	پاکستان	Str	wf	Coda	3 syl	Close	93,34		
	n	تابناک	Str	wf	Onset	2 syl	Close	74,05	18,80	34,04
	n	افسوسناک	Str	wf	Onset	3 syl	Close	55,24		
	n	جَنجال	Unstr	Non wf	Coda	2 syl	Close	106,85	23,42	28,08
	n	پنساری	Unstr	Non wf	Coda	3 syl	Close	83,42		
1 vs 3 syllables										
	n	کان	Str	wf	Coda	1 syl	Close	85,20	-8,15	-8,73
	n	پاکستان	Str	wf	Coda	3 syl	Close	93,34		
	n	دن	Unstr	wf	Coda	1 syl	Close	113,31	17,69	18,50
	n	امریکن	Unstr	wf	Coda	3 syl	Close	95,62		

	n	کان	Str	wf	Coda	1 syl	Close	85,20	-8,15	-8,73
	n	پاکستان	Str	wf	Coda	3 syl	Close	93,34		
	n	ناچ	Str	wf	Onset	1 syl	Close	84,44	29,20	52,85
	n	افسوسناک	Str	wf	Onset	3 syl	Close	55,24		
	n	نِہال	Unstr	Non wf	Onset	2 syl	Open	80,49		
	n	نب	Unstr	wf	Onset	1 syl	Close	85,16		
	n	جانب	Unstr	wf	Onset	2 syl	Close	57,98		
	n	نے	Unstr	Non wf	Onset	1 syl	Open	97,51		
1 vs 2 syllables										
	t	ٹک	Unstr	wf	Onset	1 syl	Close	11,83	-3,22	-21,42
	t	ساٹن	Unstr	wf	Onset	2 syl	Close	15,05		
	t	ٹال	Str	wf	Onset	1 syl	Close	17,02	0,74	4,57
	t	کھَٹاک	Str	wf	Onset	2 syl	Close	16,28		
	t	جٹ	Unstr	wf	Coda	1 syl	Close	16,38	-1,00	-5,75
	t	جُھرمٹ	Unstr	wf	coda	2 syl	Close	17,38		
	t	چاٹ	Str	wf	Coda	1 syl	Close	14,97	1,03	7,38
	t	لوکاٹ	Str	wf	Coda	2	Close	13,94		

						syl				
	t	ٹک	Unstr	wf	Onset	1 syl	Close	11,83	-3,22	-21,42
	t	ساﺋن	Unstr	wf	Onset	2 syl	Close	15,05		
2 vs 3 syllables										
	t	ﭨَسوے	Unstr	Non wf	Onset	2 syl	Close	21,22	3,01	16,56
	t	ﭨنڈورا	Unstr	Non wf	Onset	3 syl	Close	18,21		
	t	ﭘَﭩوار	Unstr	Non wf	Coda	2 syl	Close	27,16	7,11	35,45
	t	پﭩواری	Unstr	Non wf	Coda	3 syl	Close	20,05		
	t	جُھرمﭦ	Unstr	wf	coda	2 syl	Close	17,38	2,07	13,54
	t	انﭩرنﭦ	Unstr	wf	Coda	3 syl	Close	15,31		
	t	لوکاﭦ	Str	wf	Coda	2 syl	Close	13,94	1,79	14,71
	t	ایڈوکیﭦ	Str	wf	Coda	3 syl	Close	12,15		
	t	چﭩنی	Str	Non wf	Coda	2 syl	Close	19,08	5,93	45,10
	t	جمگھﭩوں	Str	Non wf	Coda	3 syl	Close	13,15		
	t	کھَﭩاک	Str	wf	Onset	2 syl	Close	16,28	-3,92	-19,40
	t	پروﭨین	Str	wf	Onset	3 syl	Close	20,20		
1 vs 3 syllables										
	t	چاﭦ	Str	wf	Coda	1 syl	Close	14,97	2,82	23,17

	t	ایڈوکیٹ	Str	wf	Coda	3 syl	Close		12,15		
	t	ٹال	Str	wf	Onset	1 syl	Close		17,02	-3,17	-15,72
	t	پروٹین	Str	wf	Onset	3 syl	Close		20,20		
	t	جٹ	Unstr	wf	Coda	1 syl	Close		16,38	1,07	7,01
	t	انٹرنٹ	Unstr	wf	Coda	3 syl	Close		15,31		
	t	چاٹ	Str	wf	Coda	1 syl	Close		14,97	2,82	23,17
	t	ایڈوکیٹ	Str	wf	Coda	3 syl	Close		12,15		
	t	ٹَکور	Unstr	Non wf	Onset	2 syl	Open		11,25		
	t	ٹَکور	Unstr	Non wf	Onset	2 syl	Open		11,25		
1 vs 2 syllables											
	d	ڈاک	Str	wf	Onset	1 syl	Close		16,32	-3,53	-17,77
	d	چَنڈال	Str	wf	Onset	2 syl	Close		19,85		
	d	راڈ	Str	wf	Coda	1 syl	Close		22,87	8,82	62,80
	d	گھمنڈ	Str	wf	Coda	2 syl	Close		14,05		
	d	ڈر	Unstr	wf	Onset	1 syl	Close		12,74	1,08	9,29
	d	پنڈت	Unstr	wf	Onset	2 syl	Close		11,66		

2 vs 3 syllables											
	d	گھمنڈ	Str	wf	Coda	2 syl	Close		14,05	-4,17	-22,91
	d	اسٹینڈرڈ	Str	wf	Coda	3 syl	Close		18,22		
	d	گڈوی	Str	Non wf	Coda	2 syl	Close		28,95	2,19	8,17
	d	کرنڈوا	Str	Non wf	Coda	3 syl	Close		26,77		
	d	ایڈریس	Unstr	Non wf	Coda	2 syl	Close		26,50	-2,83	-9,65
	d	اڈوکیٹ	Unstr	Non wf	Coda	3 syl	Close		29,33		
	d	ڈسچارج	Unstr	Non wf	Onset	2 syl	Close		11,71	0,19	1,64
	d	ڈپلوما	Unstr	Non wf	Onset	3 syl	Close		11,53		
	d	چَنڈال	Str	wf	Onset	2 syl	Close		19,85	3,24	19,52
	d	کوریڈار	Str	wf	Onset	3 syl	Close		16,61		
	d	اُمڈ	Unstr	wf	coda	2 syl	Close				
	d	پلاسٹڈ	Unstr	wf	Coda	3 syl	Close		15,87		
1 vs 3 syllables											
	d	راڈ	Str	wf	Coda	1 syl	Close		22,87	4,65	25,50
	d	اسٹینڈرڈ	Str	wf	Coda	3 syl	Close		18,22		
	d	مڈ	Unstr	wf	Coda	1 syl	Close		35,40	19,53	123,05
	d	پلاسٹڈ	Unstr	wf	Coda	3 syl	Close		15,87		

	d	ڈاک		Str	wf	Onset	1 syl	Close		16,32	-0,28	-1,71
	d	کوریڈار		Str	wf	Onset	3 syl	Close		16,61		
	d	راڈ		Str	wf	Coda	1 syl	Close		22,87	4,65	25,50
	d	اسٹینڈرڈ		Str	wf	Coda	3 syl	Close		18,22		
	d			Unstr	Non wf	Onset	3 syl	Open		47,83		
	d	ڈر		Unstr	wf	Onset	1 syl	Close		12,74		
	d	اُمڈ		Unstr	wf	Coda	1 syl	Close		35,40		
	d	ڈکار		Unstr	Non wf	Onset	2 syl	Open		12,96		
	d	پنڈت		Unstr	wf	Onset	2 syl	Close		11,66		
	d	ڈکار		Unstr	Non wf	Onset	2 syl	Open		12,96		
1 vs 2 syllables												
	th2	ساٹھ		Str	wf	Coda	1 syl	Close		27,02	-10,30	-27,60
	th2	چکوٹھ		Str	wf	Coda	2 syl	Close		37,32		
	th2	تھا		Unstr	Non wf	Onset	1 syl	Open		78,79	44,66	130,85
	th2	ٹُھکان		Unstr	Non wf	Onset	2 syl	Open		34,13		
	th2	ٹھگ		Unstr	wf	Onset	1 syl	Close		62,43	25,30	68,14
	th2	بیٹھک		Unstr	wf	Onset	2 syl	Close		37,13		

	th2	ٹھان		Str	wf	Onset	1 syl	Close		80,09	34,71	76,50
	th2	ٹھٹھول		Str	wf	Onset	2 syl	Close		45,38		
	th2	لٹھ		Unstr	wf	Coda	1 syl	Close		31,30	6,30	25,21
	th2	چونسٹھ		Unstr	wf	coda	2 syl	Close		25,00		
2 vs 3 syllables												
	th2	ٹھنگیر		Unstr	Non wf	Onset	2 syl	Close		49,24	4,73	10,61
	th2	ٹھٹھیارا		Unstr	Non wf	Onset	3 syl	Close		44,52		
	th2	پٹھوار		Unstr	Non wf	Coda	2 syl	Close		67,43		
	th2	اٹھوایا		Unstr	Non wf	Coda	3 syl	Close				
	th2	گٹھلی		Str	Non wf	Coda	2 syl	Close		79,36	26,46	50,01
	th2	اکسٹھواں		Str	Non wf	Coda	3 syl	Close		52,90		
	th2	چونسٹھ		Unstr	wf	coda	2 syl	Close		25,00	5,55	28,56
	th2	چھیاسٹھ		Unstr	wf	Coda	3 syl	Close		19,44		
	th2	ٹھکان		Unstr	Non wf	Onset	2 syl	Open		34,13	-0,83	-2,36
	th2	ٹھیکیدار		Unstr	Non wf	Onset	3 syl	Open		34,96		
	th2	ٹھٹھول		Str	wf	Onset	2 syl	Close		45,38	-18,96	-29,47
	th2	پرتشٹھان		Str	wf	Onset	3 syl	Close		64,34		
1 vs 3 syllables												
	th2	تھا		Unstr	Non	Onset	1	Open		78,79	43,84	125,40

				wf			syl				
	th2	ٹھیکیدار		Unstr	Non wf	Onset	3 syl	Open		34,96		
	th2	ٹھان		Str	wf	Onset	1 syl	Close		80,09	15,75	24,49
	th2	پرتشٹھان		Str	wf	Onset	3 syl	Close		64,34		
	th2	لٹھ		Unstr	wf	Coda	1 syl	Close		31,30	11,85	60,97
	th2	چھیاسٹھ		Unstr	wf	Coda	3 syl	Close		19,44		
	th2	ساٹھ		Str	wf	Coda	1 syl	Close		27,02		
	th2	بیٹھک		Unstr	wf	Onset	2 syl	Close		37,13		
	th2	چکوٹھ		Str	wf	Coda	2 syl	Close		37,32		
	th2	ٹھگ		Unstr	wf	Onset	1 syl	Close		62,43		
	th2	ساٹھ		Str	wf	Coda	1 syl	Close		27,02		
1 vs 2 syllables												
	dh2	ڈھال		Str	wf	Onset	1 syl	Close		74,27	-4,95	-6,24
	dh2	سَدّھال		Str	wf	Onset	2 syl	Close		79,22		
	dh2	ڈھل		Unstr	wf	Onset	1 syl	Close		66,91	22,33	50,09
	dh2	چوڈھل		Unstr	wf	Onset	2 syl	Close		44,58		
	dh2	ڈھا		Unstr	Non	Onset	1	Open		89,69	13,79	18,16

				wf		syl				
	dh2	ڈِھلان	Unstr	Non wf	Onset	2 syl	Open	75,90		
2 vs 3 syllables										
	dh2	ڈِھلان	Unstr	Non wf	Onset	2 syl	Open	75,90	-18,27	-19,40
	dh2	ڈُھنڈورا	Unstr	Non wf	Onset	3 syl	Open	94,17		
	dh2	ڈَھنڈار	Unstr	Non wf	Onset	2 syl	Close	49,19	17,97	57,54
	dh2	ڈُھنڈورا	Unstr	Non wf	Onset	3 syl	Close	31,23		
1 vs 3 syllables										
	dh2	ڈُھا	Unstr	Non wf	Onset	1 syl	Open	89,69	-4,49	-4,76
	dh2	ڈُھنڈورا	Unstr	Non wf	Onset	3 syl	Open	94,17		
	dh2	مڈُھ	Str	wf	Coda	1 syl	Close	42,63		
	dh2	گڈُھ	Unstr	wf	Coda	1 syl	Close	33,45		
	dh2	ڈُھال	Str	wf	Onset	1 syl	Close	74,27		
	dh2	ڈُھل	Unstr	wf	Onset	1 syl	Close	66,91		
	dh2		Str	wf	Coda	2 syl	Close			
	dh2	مڈُھ	Str	wf	Coda	1 syl	Close	42,63		

	dh2	گڈھ	Unstr	wf	Coda	1 syl	Close		33,45		
	dh2	سَڈھال	Str	wf	Onset	2 syl	Close		79,22		
	dh2	چوڈھل	Unstr	wf	Onset	2 syl	Close		44,58		
	dh2	گڈھری	Str	Non wf	Coda	2 syl	Close		48,63		
	dh2	مڈھ	Str	wf	Coda	1 syl	Close		42,63		
1 vs 2 syllables										
	s	سے	Unstr	Non wf	Onset	1 syl	Open		122,35	22,34	22,33
	s	سراب	Unstr	Non wf	Onset	2 syl	Open		100,01		
	s	پس	Unstr	wf	Coda	1 syl	Close		99,28	17,43	21,29
	s	بُھرکس	Unstr	wf	coda	2 syl	Close		81,85		
	s	پاس	Str	wf	Coda	1 syl	Close		96,98	11,35	13,25
	s	چاپلوس	Str	wf	Coda	2 syl	Close		85,64		
	s	سن	Unstr	wf	Onset	1 syl	Close		126,07	23,93	23,42
	s	یوسف	Unstr	wf	Onset	2 syl	Close		102,14		
2 vs 3 syllables										
	s	سجاد	Unstr	Non wf	Onset	2 syl	Close		93,97	2,31	2,52

	s	سرکنڈے		Unstr	Non wf	Onset	3 syl	Close		91,66		
	s	گستاخ		Unstr	Non wf	Coda	2 syl	Close		70,91	2,82	4,14
	s	ڈسپنسر		Unstr	Non wf	Coda	3 syl	Close		68,09		
	s	سراب		Unstr	Non wf	Onset	2 syl	Open		100,01	48,75	95,10
	s	سخاوت		Unstr	Non wf	Onset	3 syl	Open		51,26		
	s	بُھرکس		Unstr	wf	coda	2 syl	Close		81,85	0,64	0,78
	s	دسترس		Unstr	wf	Coda	3 syl	Close		81,22		
	s	چاپلوس		Str	wf	Coda	2 syl	Close		85,64	-4,73	-5,24
	s	تینتالیس		Str	wf	Coda	3 syl	Close		90,37		
	s	دستک		Str	Non wf	Coda	2 syl	Close		61,32	-3,44	-5,31
	s	جمناسٹک		Str	Non wf	Coda	3 syl	Close		64,77		
1 vs 3 syllables												
	s	پاس		Str	wf	Coda	1 syl	Close		96,98	6,61	7,32
	s	تینتالیس		Str	wf	Coda	3 syl	Close		90,37		
	s	پس		Unstr	wf	Coda	1 syl	Close		99,28	18,07	22,24
	s	دسترس		Unstr	wf	Coda	3 syl	Close		81,22		
	s	پاس		Str	wf	Coda	1 syl	Close		96,98	6,61	7,32
	s	تینتالیس		Str	wf	Coda	3 syl	Close		90,37		

	s	سـے		Unstr	Non wf	Onset	1 syl	Open		122,35	71,09	138,67
	s	سخاوت		Unstr	Non wf	Onset	3 syl	Open		51,26		
	s	تقسیم		Str	wf	Onset	2 syl	Close		123,01		
	s	یوسف		Unstr	wf	Onset	2 syl	Close		102,14		
	s	تقسیم		Str	wf	Onset	2 syl	Close		123,01		
	s	سـن		Unstr	wf	Onset	1 syl	Close		126,07		
1 vs 2 syllables												
	z	زد		Unstr	wf	Onset	1 syl	Close		60,19	2,05	3,53
	z	جاذب		Unstr	wf	Onset	2 syl	Close		58,13		
	z	تیز		Str	wf	Coda	1 syl	Close		60,07	-11,76	-16,38
	z	تعویذ		Str	wf	Coda	2 syl	Close		71,83		
	z	جز		Unstr	wf	Coda	1 syl	Close		86,45	17,25	24,93
	z	مرکز		Unstr	wf	coda	2 syl	Close		69,20		
2 vs 3 syllables												
	z	تعویذ		Str	wf	Coda	2 syl	Close		71,83	-1,06	-1,45
	z	دستاویز		Str	wf	Coda	3 syl	Close		72,89		
	z	ذبین		Unstr	Non wf	Onset	2 syl	Open		64,32	19,21	42,57

	z	ذبانت	Unstr	Non wf	Onset	3 syl	Open	45,12		
	z	تکذیب	Str	wf	Onset	2 syl	Close			
	z	افرازات	Str	wf	Onset	3 syl	Close	61,57		
	z	مرکز	Unstr	wf	coda	2 syl	Close	69,20	-4,31	-5,86
	z	متبارز	Unstr	wf	Coda	3 syl	Close	73,51		
	z	غزوه	Str	Non wf	Coda	2 syl	Close	74,62		
	z	پاکیزگی	Str	Non wf	Coda	3 syl	Close			
	z	غزوات	Unstr	Non wf	Coda	2 syl	Close	75,87	16,44	27,67
	z	آزموده	Unstr	Non wf	Coda	3 syl	Close	59,43		
	z	زَخار	Unstr	Non wf	Onset	2 syl	Close	64,93	15,92	32,48
	z	زنجیرا	Unstr	Non wf	Onset	3 syl	Close	49,01		
1 vs 3 syllables										
	z	تیز	Str	wf	Coda	1 syl	Close	60,07	-12,82	-17,59
	z	دستاویز	Str	wf	Coda	3 syl	Close	72,89		
	z	تیز	Str	wf	Coda	1 syl	Close	60,07	-12,82	-17,59
	z	دستاویز	Str	wf	Coda	3 syl	Close	72,89		
	z	جز	Unstr	wf	Coda	1 syl	Close	86,45	12,94	17,60
	z	متبارز	Unstr	wf	Coda	3 syl	Close	73,51		

	z	زد		Unstr	wf	Onset	1 syl	Close		60,19		
	z	افرازات		Str	wf	Onset	3 syl	Close		61,57		
	z	جاذب		Unstr	wf	Onset	2 syl	Close		58,13		
	z	ذبین		Unstr	Non wf	Onset	2 syl	Open		64,32		
	z	ذبانت		Unstr	Non wf	Onset	3 syl	Open		45,12		
1 vs 2 syllables												
	ch2	چت		Unstr	wf	Onset	1 syl	Close		43,50	-2,25	-4,92
	ch2	کیچڑ		Unstr	wf	Onset	2 syl	Close		45,75		
	ch2	سچ		Unstr	wf	Coda	1 syl	Close		57,83	-1,99	-3,33
	ch2	لالچ		Unstr	wf	coda	2 syl	Close		59,82		
	ch2	چاٹ		Str	wf	Onset	1 syl	Close		14,97	-36,24	-70,77
	ch2	پرچُون		Str	wf	Onset	2 syl	Close		51,21		
	ch2	ناچ		Str	wf	Coda	1 syl	Close		63,10	8,56	15,68
	ch2	ڈسپیچ		Str	wf	Coda	2 syl	Close		54,54		
2 vs 3 syllables												
	ch2	چِترال		Unstr	Non wf	Onset	2 syl	Close		40,60	11,16	37,90
	ch2	چٹخارا		Unstr	Non wf	Onset	3 syl	Close		29,44		

	ch2	کچنار	Unstr	Non wf	Coda	2 syl	Close		58,77	-3,13	-5,05
	ch2	پچکاری	Unstr	Non wf	Coda	3 syl	Close		61,89		
	ch2	مچلا	Str	Non wf	Coda	2 syl	Close		60,91	-12,91	-17,49
	ch2	پرموچنی	Str	Non wf	Coda	3 syl	Close		73,81		
	ch2	لالچ	Unstr	wf	coda	2 syl	Close		59,82	-12,61	-17,41
	ch2	لالونچ	Unstr	wf	Coda	3 syl	Close		72,43		
	ch2	پرچُون	Str	wf	Onset	2 syl	Close		51,21	7,77	17,90
	ch2	اتیاچار	Str	wf	Onset	3 syl	Close		43,44		
	ch2	ڈسپیچ	Str	wf	Coda	2 syl	Close		54,54	5,45	11,10
	ch2	گھچاگھچ	Str	wf	Coda	3 syl	Close		49,09		
	ch2	چٹان	Unstr	Non wf	Onset	2 syl	Open		35,42	10,79	43,79
	ch2	چراگاہ	Unstr	Non wf	Onset	3 syl	Open		24,63		
1 vs 3 syllables											
	ch2	ناچ	Str	wf	Coda	1 syl	Close		63,10	14,00	28,53
	ch2	گھچاگھچ	Str	wf	Coda	3 syl	Close		49,09		
	ch2	چاٹ	Str	wf	Onset	1 syl	Close		14,97	-28,47	-65,54
	ch2	اتیاچار	Str	wf	Onset	3 syl	Close		43,44		
	ch2	سچ	Unstr	wf	Coda	1 syl	Close		57,83	-14,60	-20,16

	ch2	لالونچ	Unstr	wf	Coda	3 syl	Close	72,43		
	ch2	ناچ	Str	wf	Coda	1 syl	Close	63,10	14,00	28,53
	ch2	گھچاگھچ	Str	wf	Coda	3 syl	Close	49,09		
	ch2	چٹان	Unstr	Non wf	Onset	2 syl	Open	35,42		
	ch2	کیچڑ	Unstr	wf	Onset	2 syl	Close	45,75		
	ch2	چراگاہ	Unstr	Non wf	Onset	3 syl	Open	24,63		
	ch2	چت	Unstr	wf	Onset	1 syl	Close	43,50		
1 vs 2 syllables										
	dZ	جو	Unstr	Non wf	Onset	1 syl	Open	36,67	8,60	30,64
	dZ	جاسوس	Unstr	Non wf	Onset	2 syl	Open	28,07		
	dZ	جن	Unstr	wf	Onset	1 syl	Close	35,32	2,28	6,89
	dZ	پنجم	Unstr	wf	Onset	2 syl	Close	33,05		
	dZ	جج	Unstr	wf	Coda	1 syl	Close	53,28	1,23	2,36
	dZ	بھاوج	Unstr	wf	coda	2 syl	Close	52,05		
	dZ	جان	Str	wf	Onset	1 syl	Close	34,06	1,08	3,28
	dZ	انجان	Str	wf	Onset	2 syl	Close	32,98		
	dZ	راج	Str	wf	Coda	1 syl	Close	55,59	5,00	9,89

					Str	wf	Coda	2 syl	Close	50,58		
2 vs 3 syllables												
	dZ	سماج			Str	wf	Coda	2 syl	Close	50,58	-3,22	-5,99
	dZ	استخراج			Str	wf	Coda	3 syl	Close	53,81		
	dZ	انجان			Str	wf	Onset	2 syl	Close	32,98	2,09	6,76
	dZ	استعجاب			Str	wf	Onset	3 syl	Close	30,89		
	dZ	بهاوج			Unstr	wf	coda	2 syl	Close	52,05	2,69	5,46
	dZ	مستخرج			Unstr	wf	Coda	3 syl	Close	49,35		
	dZ	پنجم			Unstr	wf	Onset	2 syl	Close	33,05	4,86	17,23
	dZ	پیسنجر			Unstr	wf	Onset	3 syl	Close	28,19		
	dZ	جاسوس			Unstr	Non wf	Onset	2 syl	Open	28,07	-11,33	-28,75
	dZ	جوشاندہ			Unstr	Non wf	Onset	3 syl	Open	39,40		
	dZ	سجدہ			Str	Non wf	Coda	2 syl	Close	36,76	-16,24	-30,64
	dZ	اوریجنل			Str	Non wf	Coda	3 syl	Close	52,99		
	dZ	گجرات			Unstr	Non wf	Coda	2 syl	Close	37,23	0,46	1,26
	dZ	گجریلا			Unstr	Non wf	Coda	3 syl	Close	36,76		
	dZ	جنجال			Unstr	Non wf	Onset	2 syl	Close	27,63	0,39	1,43
	dZ	جنریٹر			Unstr	Non wf	Onset	3 syl	Close	27,24		

1 vs 3 syllables										
	dZ	راج	Str	wf	Coda	1 syl	Close		55,59	1,78	3,30
	dZ	استخراج	Str	wf	Coda	3 syl	Close		53,81		
	dZ	جج	Unstr	wf	Coda	1 syl	Close		53,28	3,92	7,95
	dZ	مستخرج	Unstr	wf	Coda	3 syl	Close		49,35		
	dZ	جان	Str	wf	Onset	1 syl	Close		34,06	3,17	10,26
	dZ	استعجاب	Str	wf	Onset	3 syl	Close		30,89		
	dZ	جن	Unstr	wf	Onset	1 syl	Close		35,32	7,13	25,30
	dZ	پیسنجر	Unstr	wf	Onset	3 syl	Close		28,19		
	dZ	راج	Str	wf	Coda	1 syl	Close		55,59	1,78	3,30
	dZ	استخراج	Str	wf	Coda	3 syl	Close		53,81		
	dZ	جو	Unstr	Non wf	Onset	1 syl	Open		36,67	-2,72	-6,92
	dZ	جوشانده	Unstr	Non wf	Onset	3 syl	Open		39,40		
1 vs 2 syllables										
	r	رو	Unstr	Non wf	Onset	1 syl	Open		43,48	-1,64	-3,63
	r	رُمال	Unstr	Non wf	Onset	2 syl	Open		45,12		
	r	پر	Unstr	wf	Coda	1 syl	Close		44,44	7,75	21,12
	r	کافر	Unstr	wf	coda	2 syl	Close		36,69		

	r	رب	Unstr	wf	Onset	1 syl	Close	40,60	1,97	5,11
	r	حسرت	Unstr	wf	Onset	2 syl	Close	38,62		
	r	تیر	Str	wf	Coda	1 syl	Close	46,70	4,22	9,94
	r	تدبیر	Str	wf	Coda	2 syl	Close	42,48		
	r	رات	Str	wf	Onset	1 syl	Close	51,99	6,99	15,54
	r	تقریر	Str	wf	Onset	2 syl	Close	45,00		
2 vs 3 syllables										
	r	رمضان	Unstr	Non wf	Onset	2 syl	Close	28,84	-6,42	-18,21
	r	رضوانی	Unstr	Non wf	Onset	3 syl	Close	35,26		
	r	حرکات	Unstr	Non wf	Coda	2 syl	Close	37,90	-4,14	-9,85
	r	چروابا	Unstr	Non wf	Coda	3 syl	Close	42,04		
	r	حسرت	Unstr	wf	Onset	2 syl	Close	38,62	1,79	4,86
	r	سنسکرت	Unstr	wf	Onset	3 syl	Close	36,84		
	r	پرده	Str	Non wf	Coda	2 syl	Close	45,46	14,45	46,61
	r	کارکرده	Str	Non wf	Coda	3 syl	Close	31,01		
	r	کافر	Unstr	wf	coda	2 syl	Close	36,69	-6,60	-15,25
	r	امرتسر	Unstr	wf	Coda	3 syl	Close	43,30		
	r	تدبیر	Str	wf	Coda	2 syl	Close	42,48	-1,42	-3,23

	r	كاروبار	Str	wf	Coda	3 syl	Close	43,89		
	r	تقریر	Str	wf	Onset	2 syl	Close	45,00	12,19	37,16
	r	استخراج	Str	wf	Onset	3 syl	Close	32,81		
1 vs 3 syllables										
	r	تیر	Str	wf	Coda	1 syl	Close	46,70	2,81	6,39
	r	کاروبار	Str	wf	Coda	3 syl	Close	43,89		
	r	رات	Str	wf	Onset	1 syl	Close	51,99	19,18	58,47
	r	استخراج	Str	wf	Onset	3 syl	Close	32,81		
	r	رب	Unstr	wf	Onset	1 syl	Close	40,60	3,76	10,21
	r	سنسکرت	Unstr	wf	Onset	3 syl	Close	36,84		
	r	پر	Unstr	wf	Coda	1 syl	Close	44,44	1,15	2,65
	r	امرتسر	Unstr	wf	Coda	3 syl	Close	43,30		
	r	تیر	Str	wf	Coda	1 syl	Close	46,70	2,81	6,39
	r	کاروبار	Str	wf	Coda	3 syl	Close	43,89		
	r	رُمال	Unstr	Non wf	Onset	2 syl	Open	45,12		
	r	رو	Unstr	Non wf	Onset	1 syl	Open	43,48		
1 vs 2 syllables										

	rr2	گاڑ	Str	wf	Coda	1 syl	Close		26,31	0,37	1,42
	rr2	کُھدیڑ	Str	wf	Coda	2 syl	Close		25,94		
	rr2	جڑ	Unstr	wf	Coda	1 syl	Close		32,70	4,17	14,62
	rr2	گیدڑ	Unstr	wf	coda	2 syl	Close		28,53		
2 vs 3 syllables										
	rr2	کُھدیڑ	Str	wf	Coda	2 syl	Close		25,94	-8,88	-25,50
	rr2	قنادیڑ	Str	wf	Coda	3 syl	Close		34,82		
	rr2	گڑھا	Str	Non wf	Coda	2 syl	Close		35,52	3,28	10,18
	rr2	پھلجڑیا	Str	Non wf	Coda	3 syl	Close		32,24		
	rr2	پڑتال	Unstr	Non wf	Coda	2 syl	Close		48,81	21,68	79,89
	rr2	پڑپوتا	Unstr	Non wf	Coda	3 syl	Close		27,13		
	rr2	گیدڑ	Unstr	wf	coda	2 syl	Close		28,53	1,06	3,87
	rr2	چمگادڑ	Unstr	wf	Coda	3 syl	Close		27,46		
1 vs 3 syllables										
	rr2	گاڑ	Str	wf	Coda	1 syl	Close		26,31	-8,51	-24,44
	rr2	قنادیڑ	Str	wf	Coda	3 syl	Close		34,82		
	rr2	گاڑ	Str	wf	Coda	1 syl	Close		26,31	-8,51	-24,44
	rr2	قنادیڑ	Str	wf	Coda	3 syl	Close		34,82		

	rr2	جڑ		Unstr	wf	Coda	1 syl	Close		32,70	5,23	19,06
	rr2	چمگادڑ		Unstr	wf	Coda	3 syl	Close		27,46		
	rr2			Unstr	Non wf	Onset	3 syl	Open		67,30		
	rr2	دھڑام		Str	wf	Onset	2 syl	Close		39,02		
	rr2	دھڑام		Str	wf	Onset	2 syl	Close		39,02		
	rr2	کھوڑل		Unstr	wf	Onset	2 syl	Close		25,72		
	rr2			Unstr	Non wf	Onset	3 syl	Open		67,30		
1 vs 2 syllables												
	l	تیل		Str	wf	Coda	1 syl	Close		88,35	5,96	7,23
	l	قندیل		Str	wf	Coda	2 syl	Close		82,40		
	l	مل		Unstr	wf	Coda	1 syl	Close		107,23	29,71	38,32
	l	پاگل		Unstr	wf	coda	2 syl	Close		77,52		
	l	لو		Unstr	Non wf	Onset	1 syl	Open		87,67	16,75	23,63
	l	لحاظ		Unstr	Non wf	Onset	2 syl	Open		70,91		
	l	لت		Unstr	wf	Onset	1 syl	Close		83,14	15,43	22,78
	l	پالک		Unstr	wf	Onset	2 syl	Close		67,71		
	l	لاش		Str	wf	Onset	1 syl	Close		79,41	19,93	33,50
	l	چالاک		Str	wf	Onset	2 syl	Close		59,48		

2 vs 3 syllables										
	I	للکار	Unstr	Non wf	Onset	2 syl	Close	78,06	6,20	8,63
	I	لٹریچر	Unstr	Non wf	Onset	3 syl	Close	71,86		
	I	ملتان	Unstr	Non wf	Coda	2 syl	Close	72,45	1,56	2,20
	I	الماری	Unstr	Non wf	Coda	3 syl	Close	70,88		
	I	چلنا	Str	Non wf	Coda	2 syl	Close	90,44	-7,87	-8,00
	I	عبداللہ	Str	Non wf	Coda	3 syl	Close	98,31		
	I	پاگل	Unstr	wf	coda	2 syl	Close	77,52	3,36	4,53
	I	آرٹیکل	Unstr	wf	Coda	3 syl	Close	74,17		
	I	قندیل	Str	wf	Coda	2 syl	Close	82,40	-10,92	-11,70
	I	ابابیل	Str	wf	Coda	3 syl	Close	93,31		
	I	پالک	Unstr	wf	Onset	2 syl	Close	67,71	11,05	19,51
	I	مبادلت	Unstr	wf	Onset	3 syl	Close	56,66		
	I	چالاک	Str	wf	Onset	2 syl	Close	59,48	-10,70	-15,25
	I	استقلال	Str	wf	Onset	3 syl	Close	70,19		
1 vs 3 syllables										
	I	تیل	Str	wf	Coda	1 syl	Close	88,35	-4,96	-5,32
	I	ابابیل	Str	wf	Coda	3 syl	Close	93,31		

	I	لت	Unstr	wf	Onset	1 syl	Close	83,14	26,48	46,74
	I	مبادلت	Unstr	wf	Onset	3 syl	Close	56,66		
	I	لاش	Str	wf	Onset	1 syl	Close	79,41	9,22	13,14
	I	استقلال	Str	wf	Onset	3 syl	Close	70,19		
	I	مل	Unstr	wf	Coda	1 syl	Close	107,23	33,07	44,59
	I	آرٹیکل	Unstr	wf	Coda	3 syl	Close	74,17		
	I	تیل	Str	wf	Coda	1 syl	Close	88,35	-4,96	-5,32
	I	ابابیل	Str	wf	Coda	3 syl	Close	93,31		
	I	لحاظ	Unstr	Non wf	Onset	2 syl	Open	70,91		
	I	لو	Unstr	Non wf	Onset	1 syl	Open	87,67		

Appendix O: SUM-OF-PRODUCTS RESULTS FOR VOWELS

Word	Vowel	Avg duration speaker 1	Avg duration speaker 2	Avg duration speaker 3	Avg duration speaker 4	Avg duration speaker 5	Avg duration speaker 6	Average duration	Standard deviation	SOP duration
کوٹا	ɑ	129.06	128.89	129.06	128.98	141.82	139.31	132.85	6.02	127.81
کاتب	ɑ	112.55	106.81	112.55	109.68	99.93	102.75	107.38	5.22	136.82
ٹانگا	ɑ	132.39	129.52	132.39	130.96	171.03	159.47	142.63	17.93	136.82

پاگل	ɑ	133.47	131.11	133.47	132.29	134.17	109.26	128.96	9.71	136.82
کدہ	ɑ	134.34	120.09	134.34	127.22	183.57	132.19	138.62	22.68	126.61
ڈاکا	ɑ	126.92	116.37	126.92	121.65	127.35	108.83	121.34	7.48	136.82
کاٹنا	ɑ	118.55	118.90	118.55	118.73	149.79	149.69	129.04	16.04	136.82
کھاتا	ɑ	104.02	93.39	104.02	98.71	86.08	76.807	93.84	10.79	136.82
ڈھاکہ	ɑ	115.89	122.83	115.89	119.36	100.42	71.48	107.65	19.31	136.82
تاکید	ɑ	126.62	118.57	126.62	122.60	99.52	108.65	117.10	10.90	127.81
لوکاٹ	ɑ	158.61	150.92	158.61	154.76	203.03	200.64	171.09	23.99	136.82
دَھکا	ɑ	120.45	104.37	120.45	112.41	145.15	135.54	123.06	14.97	127.81
پھٹاک	ɑ	117.06	123.31	117.06	120.19	182.39	183.33	140.56	32.85	127.81
تابوت	ɑ	129.95	126.09	129.95	128.02	107.63	120.26	123.65	8.63	126.739
ڈاکیا	ɑ	108.67	118.83	108.67	113.75	123.18	110.96	114.01	5.90	127.81
داتری	ɑ	128.83	120.07	128.83	124.45	133.36	123.95	126.58	4.69	136.82
پادری	ɑ	131.30	130.02	131.30	130.66	140.59	135.68	133.26	4.11	136.82
گدھا	ɑ	124.08	122.03	124.08	123.05	146.57	141.67	130.25	10.89	127.296
کوٹا	u	114.65	64.50	114.65	89.58	85.31	87.213	92.65	19.25	131.69
دُوپوں	u	126.18	102.63	126.18	114.41	96.33	109.5	112.54	12.21	131.69

کوُٹنا	u	105.45	85.72	105.45	95.59	107.5	118.09	102.97	11.08	131.69
تھوُکا	u	98.29	63.44	98.29	80.86	77.16	73.265	81.88	13.97	131.69
ڈاکو	u	101.31	74.80	101.31	88.06	97.93	87.485	91.82	10.39	126.57
کرتوت	u	144.69	104.24	144.69	124.47	167.71	145.75	138.59	21.69	131.69
تابوت	u	125.03	116.21	125.03	120.62	153.84	137.58	129.72	13.80	131.69
کدو	u	121.44	95.18	121.44	108.31	125.11	128.59	116.68	12.57	126.57
مکتوُب	u	141.24	115.45	141.24	128.35	154.43	139.86	136.76	13.32	131.69
رکوُد	u	143.05	137.68	143.05	140.37	162.8	193.96	153.48	21.75	131.69
ڈوُبتے	u	97.23	101.53	97.23	99.38	125.34	128.4	108.19	14.59	131.69
کیکر	i	101.70	75.32	101.70	88.51	75.3	72.67	85.87	13.46	121.86
گیتوں	i	115.42	90.34	115.42	102.88	100.73	106.18	105.16	9.55	121.86
ترکیب	i	123.63	119.17	123.63	121.40	128.78	141.45	126.34	8.06	119.64
رکھی	i	77.16	78.75	77.16	77.96	103.29	90.92	84.21	10.75	119.64
گاتی	i	102.67	99.27	102.67	100.97	81.37	119.54	101.08	12.15	119.64
تاکید	i	118.18	112.10	118.18	115.14	156.59	159.61	129.97	21.93	121.86
دیپال	i	103.87	88.84	103.87	96.35	58.04	82.1	88.85	17.33	119.64
ٹڈی	i	105.64	70.32	105.64	87.98	60.98	115.32	90.98	21.72	117.891

کبھی	i	132.43	105.58	132.43	119.00	121.43	141.58	125.41	12.73	117.891
	ɪ									
پیدل	æ	92.28	115.44	92.28	103.86	113.7	93.895	101.91	10.73	146.45
بیٹھک	æ	105.51	116.21	105.51	110.86	113.39	102.07	108.92	5.42	146.45
لبیک	æ	152.17	142.50	152.17	147.33	186.49	148.74	154.90	15.89	137.55
ٹیکسی	æ	98.55	67.70	98.55	83.12	99.4	71.195	86.42	14.53	146.45
بیٹھتے	æ	120.70	133.27	120.70	126.98	141.74	138.01	130.23	8.88	146.45
بیٹھک	ə	62.28	66.26	62.28	64.27	68.65	60.22	63.99	3.07	70.42
قتِل	ə	63.32	44.52	63.32	53.92	56.82	35.64	52.92	10.97	85.13
کدہ	ə	67.88	59.30	67.88	63.59	71.27	51.785	63.62	7.12	85.13
گھر	ə	84.48	66.35	84.48	75.42	81.58	69.91	77.04	7.74	85.13
تِکڑَا	ə	46.41	57.48	46.41	51.95	52.91	39.13	49.05	6.43	85.13
تکرار	ə	51.42	45.43	51.42	48.43	51.77	40.6	48.18	4.45	70.42
موکد	ə	71.13	63.97	71.13	67.55	96.35	72.275	73.73	11.50	70.42
مکِتب	ə	60.54	55.36	60.54	57.95	63.04	64.365	60.30	3.29	70.42
لاگت	ə	73.38	69.74	73.38	71.56	89.29	68.42	74.30	7.61	70.42
پھٹا	ə	62.88	62.64	62.88	62.76	69.09	49.095	61.56	6.61	85.13

تِھکا	ə		78.54	58.78	78.54	68.66	78.74	48.595		68.64	12.63		70.42
تِھپکا	ə		60.76	46.45	60.76	53.61	53.9	42.355		52.97	7.45		85.13
کھٹاک	ə		80.63	50.03	80.63	65.33	56.65	46.605		63.31	14.86		70.42
کِھٹک	ə		78.60	70.91	78.60	74.76	91.1	54.97		74.82	11.86		85.13
گِھٹا	ə		80.19	69.87	80.19	75.03	86.55	69.155		76.83	6.75		85.13
گھٹور	ə		92.06	57.73	92.06	74.90	87.59	74.025		79.73	13.46		70.42
گھپلا	ə		64.77	57.02	64.77	60.89	81.41	55.58		64.07	9.31		85.13
کپاٹ	ə		40.49	29.26	40.49	34.88	43.49	41.275		38.31	5.27		70.42
پھدک	ə		79.71	70.58	79.71	75.15	87.09	78.42		78.44	5.49		85.13
برکت	ə		58.38	57.74	58.38	58.06	66.43	69.535		61.42	5.18		70.42
پدید	ə		57.17	53.26	57.17	55.22	63.47	49.47		55.96	4.68		70.95
ڈکیت	ə		54.01	35.61	54.01	44.81	65.44	47.02		50.15	10.13		70.42
کدو	ə		54.25	53.97	54.25	54.11	64.91	52.55		55.67	4.57		85.13
ٹِٹور	ə		61.92	46.65	61.92	54.29	67.5	53.66		57.66	7.50		72.76
کھڈا	ə		60.03	60.84	60.03	60.44	69.39	41.445		58.70	9.20		85.66
کتر	ʊ		48.83	43.51	48.83	46.17	44.56	36.235		44.69	4.68		71.86
پَتو ل	ʊ		61.72	56.14	61.72	58.93	59.69	33.44		55.27	10.89		71.86

ٹلکنا	ں	47.56	45.90	47.56	46.73	46.94	32.775	44.58	5.81	71.86
چابک	ں	55.19	55.30	55.19	55.25	76.4	40.765	56.35	11.40	74.99
ٹھکا	ں	59.03	41.87	59.03	50.45	63.16	40.155	52.28	9.68	74.99
کھدتا	ں	45.65	52.46	45.65	49.05	53.36	55.42	50.26	4.13	71.86
گِھٹا	ں	68.09	52.20	68.09	60.14	61.43	57.11	61.18	6.22	71.86
بھکتو	ں	59.78	56.05	59.78	57.92	74.86	37.01	57.57	12.12	71.86
دُھتکار	ں	70.65	65.24	70.65	67.95	79.34	76.76	71.76	5.33	74.99
پکار	ں	51.86	35.86	51.86	43.86	51.28	127.61	60.39	33.53	74.99
کگر	ں	53.75	51.84	53.75	52.80	45.89	40.755	49.80	5.32	71.86
دُکھنا	ں	53.99	48.30	53.99	51.14	57.2	39.88	50.75	6.11	71.86
دُکان	ں	46.21	51.06	46.21	48.64	47.64	46.205	47.66	1.94	74.99
گُٹھلی	ں	63.55	55.19	63.55	59.37	79.21	47.55	61.40	10.59	71.86
کبڑا	ں	42.63	46.96	42.63	44.80	47.72	40.66	44.23	2.75	71.86
کھدیڑ	ں	48.94	36.85	48.94	42.89	50.83	53.095	46.92	5.99	74.99
ٹھڈا	ں	59.01	37.01	59.01	48.01	57.02	50.143	51.70	8.57	68.46
کھجے	ں	53.50	39.65	53.50	46.58	56.77	33.38	47.23	9.16	68.46
	ﮨ									
کاتب	ا	59.76	44.59	59.76	52.18	61.67	73.765	58.62	9.79	58.34

Word	Consonant							Average duration	Standard deviation		SOP duration
پدر	I	55.13	60.37	55.13	57.75	67.78	46.61	57.13	6.97		63.88
بٹھا	I	53.96	46.74	53.96	50.35	54.82	51.72	51.93	3.04		63.88
کِتنا	I	38.97	33.58	38.97	36.28	47.3	30.7	37.63	5.72		63.88
ٹکیا	I	50.82	36.16	50.82	43.49	58.55	37.805	46.28	8.65		58.34
ثابت	I	56.79	59.67	56.79	58.23	72.28	76.385	63.36	8.67		58.34
پھٹا	I	65.14	57.96	65.14	61.55	73.84	47.345	61.83	8.84		63.88
پھٹکا	I	68.11	41.25	68.11	54.68	74.13	48.525	59.14	12.95		63.88
پکاس	I	50.29	47.25	50.29	48.77	44.01	33.435	45.67	6.44		58.34
تِتلی	I	46.39	67.54	46.39	56.97	54.06	48.565	53.32	8.18		63.88
بِکھیر	I	42.67	47.81	42.67	45.24	61.35	55.45	49.20	7.61		58.34
ٹڈا	I	62.27	50.26	62.27	56.26	61.1	56.13	58.05	4.74		63.88
ٹھِگنا	I	67.46	53.57	67.46	60.51	52.93	54.22	59.36	6.84		63.985

Appendix P: SUM-OF-PRODUCTS RESULTS FOR CONSONANTS

Word	Consonant	Avg duration speaker 1	Avg duration speaker 2	Avg duration speaker 3	Avg duration speaker 4	Avg duration speaker 5	Avg duration speaker 6	Average duration	Standard deviation		SOP duration
منان	m	93.33	79.58	84.83	93.80	85.91	85.64	87.18	5.46		90.77
نسرین	n	80.94	80.73	78.87	78.05	80.18	83.55	80.38	1.91		89.26
تَ سوے	t	27.92	38.92	11.47	11.77	26.10	11.16	21.22	11.56		29.29

ڈسچارج	d	15.59	10.28	12.28	8.83	12.72	10.58	11.71	2.37	26.29
تَھنگیر	tH	45.45	35.73	43.41	58.84	41.53	70.49	49.24	12.91	60.42
ڈَھنڈار	dH	78.33	48.75	24.61	70.89	50.56	22.01	49.19	23.09	61.24
سجاد	s	85.47	85.59	95.65	112.65	88.90	95.57	93.97	10.22	95.61
زَخار	z	83.22	54.88	74.09	60.14	70.73	46.55	64.93	13.52	66.74
چِترال	tS	35.22	45.59	27.80	54.41	36.20	44.36	40.60	9.40	59.44
جنجال	dZ	31.15	22.98	29.09	31.14	27.74	23.69	27.63	3.58	46.15
رمضان	r	31.38	28.64	30.81	30.27	30.27	21.65	28.84	3.64	43.87
للکار	l	58.29	90.56	55.72	82.20	68.19	113.39	78.06	21.95	77.58
رمضان	m	113.02	112.75	99.02	115.77	108.26	119.17	111.33	7.03	90.79
جَنجال	n	120.97	100.44	104.09	89.89	108.50	117.21	106.85	11.37	92.67
پَٹوار	t	52.84	27.60	14.44	24.71	31.62	11.78	27.16	14.72	18.94
ایڈریس	d	44.98	22.53	20.91	19.54	29.48	21.53	26.50	9.70	50.01
پَٹھوارؔ	tH	75.06	34.09	84.40	90.77	64.52	55.72	67.43	20.73	32.22
گستاخ	s	75.53	59.61	73.55	84.05	69.57	63.16	70.91	8.84	88.64
غزوات	z	78.45	58.61	83.89	97.18	73.65	63.42	75.87	14.02	67.42
کچنار	tS	37.24	37.04	57.85	82.27	44.04	94.16	58.77	24.32	90.33
گجرات	dZ	30.37	32.47	38.56	43.75	33.80	44.41	37.23	5.95	63.78
حرکات	r	39.35	27.47	45.80	39.14	37.54	38.12	37.90	5.92	43.02
پڑتال	R	138.36	25.09	20.16	30.77	61.20	17.26	48.81	46.64	31.54

ملتان	l	79.40	78.17	74.17	66.10	77.24	59.60	72.45	7.90	78.13

مسلم	m	91.34	67.44	75.44	112.69	78.07	80.22	84.20	15.96	93.66
نرگس	n	66.13	67.67	63.10	86.11	65.63	87.56	72.70	11.06	92.49
ٹخنا	t	88.15	10.51	11.04	10.22	36.57	8.66	27.52	31.54	10.89
ڈگمگ	d	114.02	10.22	14.04	8.83	46.09	14.36	34.60	41.30	49.05
ٹُھسکی	tH	54.76	30.86	41.47	57.96	42.36	49.20	46.10	9.93	80.40
سجدے	s	74.55	85.05	105.13	135.28	88.24	112.30	100.09	22.05	97.90
زمزم	z	96.10	50.69	51.29	58.22	66.02	51.27	62.26	17.61	62.03
چٹنی	tS	54.54	26.90	24.86	57.51	35.44	53.36	42.10	14.77	67.62
جرنل	dZ	104.06	27.04	36.56	30.61	55.89	30.84	47.50	29.57	58.21
رستم	r	116.10	36.69	31.81	36.04	61.53	20.30	50.41	34.89	57.36
لنگڑا	l	85.83	73.08	88.94	97.42	82.62	91.21	86.52	8.28	83.74

قمری	m	85.09	84.15	85.45	125.40	84.90	103.43	94.74	16.76	93.68
پِنجر	n	100.99	94.67	106.97	125.50	100.88	92.54	103.59	11.89	95.90
چٹنی	t	22.29	16.78	29.11	13.42	22.72	10.17	19.08	6.94	0.54
گَڈوی	d	45.33	24.82	25.91	20.23	32.02	25.40	28.95	8.86	72.77
گٹھلی	tH	48.61	75.81	59.33	138.45	61.25	92.68	79.36	32.73	52.20
گڈھری	dH	75.80	38.79	20.73	89.42	45.11	21.95	48.63	28.29	88.68
دستك	s	56.19	56.66	53.86	70.30	55.57	75.36	61.32	9.10	90.93

غزوہ	z	81.80	72.11	77.97	80.51	77.29	58.01	74.62	8.80	62.71
مچلا	tS	25.77	45.69	52.12	95.16	41.19	105.50	60.91	31.92	98.51
سجدہ	dZ	34.11	34.48	24.80	55.09	31.13	40.93	36.76	10.40	75.84
پردہ	r	84.46	30.33	31.88	48.58	48.89	28.60	45.46	21.16	56.51
گڑھا	R	44.32	32.34	28.63	26.44	35.09	46.29	35.52	8.17	38.45
چلنا	l	92.45	110.26	89.84	71.42	97.51	81.20	90.44	13.38	84.29
مِثال	m	79.95	61.62	68.25	80.41	69.94	78.20	73.06	7.64	90.77
نِہال	n	94.12	71.81	71.53	80.53	79.15	85.78	80.49	8.62	89.26
تَکور	t	13.97	10.33	10.88	11.33	11.73	9.24	11.25	1.59	29.29
ڈکار	d	19.84	11.24	12.65	8.84	14.58	10.60	12.96	3.89	26.29
تُھکان	tH	51.45	24.99	26.07	26.02	34.17	42.08	34.13	10.75	60.42
ڈِھلان	dH	97.65	61.89	64.98	71.44	74.84	84.62	75.90	13.31	61.24
سراب	s	103.26	88.47	86.26	129.44	92.66	99.99	100.01	15.83	95.61
ذہین	z	86.86	53.93	62.16	53.38	67.65	61.97	64.32	12.30	66.74
چٹان	tS	16.37	33.14	28.23	57.09	25.91	51.78	35.42	15.79	59.44
جاسوس	dZ	29.67	28.18	29.93	27.95	29.26	23.43	28.07	2.41	46.15
رُمال	r	80.59	37.17	32.50	32.25	50.09	38.11	45.12	18.55	43.87
لحاظ	l	64.01	75.48	66.02	77.02	68.50	74.45	70.91	5.44	77.58
ماتم	m	81.60	62.57	77.94	87.09	74.04	91.53	79.13	10.24	93.66

ناٹک	n	75.91	53.46	79.91	100.11	69.76	87.36	77.75	15.84	92.49
ٹوپی	t	10.26	16.98	13.63	9.15	13.62	9.52	12.19	3.07	10.89
ڈولی	d	36.94	15.25	15.69	8.92	22.63	14.69	19.02	9.80	49.05
ٹھوکر	tH	57.69	41.04	43.32	52.20	47.35	53.90	49.25	6.44	80.40
ڈھارس	dH	80.00	71.08	79.50	85.91	76.86	95.97	81.55	8.55	105.84
ساتھی	s	77.75	78.07	95.79	116.83	83.87	96.16	91.41	14.90	97.90
زامور	z	50.05	54.42	67.74	62.14	57.40	56.37	58.02	6.18	62.03
چاکو	tS	30.22	32.76	34.04	40.77	32.34	53.55	37.28	8.74	67.62
جامن	dZ	30.84	30.13	36.14	42.21	32.37	33.63	34.22	4.46	58.21
روٹی	r	108.33	36.84	33.74	38.24	59.64	39.82	52.77	28.74	57.36
لاغر	l	76.91	62.68	85.65	79.23	75.08	72.24	75.30	7.67	83.74

Appendix Q: ANOVA RESULTS FOR VOWELS:

ɑ							ə						
Source of Variation	SS	df	MS	F	P-value	F crit	Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4840.97	5.00	968.19	4.63	0.00	2.30	Between Groups	1773.14	5.00	354.63	2.82	0.02	2.28
Within Groups	21340.93	102.00	209.22				Within Groups	18112.15	144.00	125.78			
Total	26181.90	107.00					Total	19885.29	149.00				
u							ʊ						
Source of Variation	SS	df	MS	F	P-value	F crit	Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2660.48	5.00	532.10	1.91	0.11	2.37	Between Groups	2297.82	5.00	459.56	6.07	0.00	2.30
Within Groups	16737.35	60.00	278.96				Within Groups	7725.59	102.00	75.74			

	SS	df	MS	F	P-value	F crit			SS	df	MS	F	P-value	F crit
Total	19397.82	65.00						Total	10023.41	107.00				
i								**ɪ**						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2045.79	5.00	409.16	1.67	0.16	2.41		Between Groups	698.35	5.00	139.67	2.66	0.03	2.34
Within Groups	11734.10	48.00	244.46					Within Groups	3774.69	72.00	52.43			
Total	13779.89	53.00						Total	4473.05	77.00				
ae														
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*								
Between Groups	159.16	5.00	31.83	0.07	1.00	2.62								
Within Groups	11604.84	24.00	483.53											
Total	11764.00	29.00												

Appendix R: ANOVA RESULTS FOR CONSONANTS:

m								**n**						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	494.70	5.00	98.94	1.37	0.26	2.53		Between Groups	326.49	5.00	65.30	0.67	0.65	2.53
Within Groups	2161.71	30.00	72.06					Within Groups	2924.39	30.00	97.48			
Total	2656.41	35.00						Total	3250.88	35.00				
t								**d**						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1070.04	5.00	214.01	1.07	0.40	2.53		Between Groups	879.68	5.00	175.94	0.77	0.58	2.53
Within Groups	5999.18	30.00	199.97					Within Groups	6898.75	30.00	229.96			
Total	7069.22	35.00						Total	7778.43	35.00				
t^h								d^h						

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1208.90	5.00	241.78	0.79	0.57	2.53
Within Groups	9203.93	30.00	306.80			
Total	10412.82	35.00				

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1588.00	5.00	317.60	0.87	0.52	2.77
Within Groups	6590.49	18.00	366.14			
Total	8178.48	23.00				

s

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	611.87	5.00	122.37	0.94	0.47	2.53
Within Groups	3885.64	30.00	129.52			
Total	4497.51	35.00				

z

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	586.80	5.00	117.36	2.54	0.05	2.53
Within Groups	1387.78	30.00	46.26			
Total	1974.58	35.00				

tʃ

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6413.42	5.00	1282.68	7.90	0.00	2.53
Within Groups	4873.07	30.00	162.44			
Total	11286.49	35.00				

dʒ

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	432.74	5.00	86.55	0.80	0.56	2.53
Within Groups	3233.38	30.00	107.78			
Total	3666.13	35.00				

r

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2084.42	5.00	416.88	3.11	0.02	2.53
Within Groups	4026.50	30.00	134.22			
Total	6110.91	35.00				

l

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	188.30	5.00	37.66	0.54	0.74	2.53
Within Groups	2084.42	30.00	69.48			
Total	2272.72	35.00				

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Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3694.20	5.00	738.84	0.80	0.59	4.39
Within Groups	5526.36	6.00	921.06			
Total	9220.56	11.00				