Visual Recognition of Permuted Words

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ABSTRACT

In current study we examine how letter permutation affects in visual recognition of words for two orthographically dissimilar languages, Urdu* and German. We present the hypothesis that recognition or reading of permuted and non-permuted words are two distinct mental level processes, and that people use different strategies in handling permuted words as compared to normal words. A comparison between reading behavior of people in these languages is also presented. We present our study in context of dual route theories of reading and it is observed that the dual-route theory is consistent with explanation of our hypothesis of distinction in underlying cognitive behavior for reading permuted and non-permuted words. We conducted three experiments in lexical decision tasks to analyze how reading is degraded or affected by letter permutation. We performed analysis of variance (ANOVA), distribution free rank test, and t-test to determine the significance differences in response time latencies for two classes of data. Results showed that the recognition accuracy for permuted words is decreased 31% in case of Urdu and 11% in case of German language. We also found a considerable difference in reading behavior for cursive and alphabetic languages and it is observed that reading of Urdu is comparatively slower than reading of German due to characteristics of cursive script.

Keywords: Human Cognition, Visual Word Recognition, Reading Permuted Words, Urdu Reading, Models of Reading, Dual Route Models of Reading, Psychophysical Methods, Psycholinguistics

1. INTRODUCTION

Visual word recognition is a high level cognitive activity and people process a lot of information in different areas of brain unconsciously. Better understanding of this cognitive activity has been central to research in optical character recognition, language processing, and attention, memory and brain functions. Although the more important goal of psycholinguistic researchers would be to analyze how language is processed at higher level such as clauses or sentences, but a lot of research has been pursued at word level because words carry interesting characteristics like orthography, phonology, semantics and are relatively well defined patterns for formal mathematical models.

There is a large debate in reading and cognitive research about visual word recognition and reading aloud. Cattell[1,2] is considered to be the first who suggested that words are recognized as a complete unit by visualizing the ascending, descending and neutral patterns of individual characters. Word shape model is also supported by Woodworth,[3] Smith,[4] and Fisher[5] as they found that readers can read lowercase text 5-10 % faster than uppercase text. Healy and Cunnigham[6] reported that the proof reading errors are affected by word shape in the lowercase passage but not in the uppercase passages. Gough[7] proposed that words are recognized as letter by letter serially from left to right.

Another general theory is that words are formed by letters in a word and this letter information is used to recognize the whole word. Analytical models such as the search model,[8] the interactive-activation model,[9] the activation-verification model[10] and the multiple read-out model[11] assumed that information about visual word shape is lost early in the process of word recognition therefore the particular word shape that words take is

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*http://en.wikipedia.org/wiki/Urdu_language irrelevant to this process. However Rayner and Pollatsek[12] have concluded from the results of many studies that both types of processing (holistically and analytically) are involved in visual word recognition. Besner and Johnston[13] proposed a multiple-route model and they suggested that a lexical decision response can be achieved by three routes: (1) using a visual familiarity assessment i.e via global word shape), (2) using an orthographic familiarity assessment based on overall lexical activation in the orthographic lexicon and (3) word identification on the basis of letter-level codes.

Evolution and development of computational models, for example, dual route cascadded model (DRC)[14] and distributed developmental model[15] of reading provided theoretical implementations from different schools of thoughts. Initially these models were developed to provide print-to-speech or spelling to sound correspondence. However, the main goal in reading is how people understand text. There is a longstanding debate that, are words read on visual basis (computing meanings from orthographic patterns or spellings) or from phonologically (from spelling to internal phonological pattern to meaning)? In fact, a skilled reader could understand the meaning of a word directly from its spellings or orthographic representation. However, orthographic patterns (letters, syllables etc.) that represents sounds (phonemes), provide another path that spelling could be translated into a phonological representation that is then used to compute the meaning of a whole word. These two processes of reading have traditionally been termed direct(orthography to meaning) and phonologically-mediated(orthography to phonology to meaning) lexical access or dual-route. Marshall and Newcombe[16] were first to express these ideas in box-and-arrow model of reading and later on Baron[17] provided a detailed explanation. Interestingly, This model had modern features like lexical-non semantic route for reading aloud (direct route from orthography to phonology) and had a possibility of route from orthography to semantics that uses word parts and as well as that uses whole words. This model also accounted a dual-route for word comprehension. Harm and Seidenberg[18] were first to provide how meaning is computed in a system in which both visual and phonological mediated pathways are available. There model was based on previous models of reading[15, 19, 20] where as, these earlier model only emphasized on print to sound but not on print to meaning. This model is based on a network of separate layers of units. These units represent the spelling and pronunciation of words. These representations are distributed and the finite set of units within a layer is used to represent a very large set of patterns (as an alphabet represents many words). The orthographic representation might be composed of letters or their visual features and phonological representation could be composed of phonemes or phonetic feature. The activation of semantic units build up from both pathways simultaneously. The meaning of a word is determined by joint working of two components and division of labor between them. This division of labor varies as a function of different factors like word frequency, spelling-sound consistency etc., and amount of experience (skilled vs non-skilled reader). It is concluded from the model that the skilled reading involves the visual and phonological pathways working together and contribution of each pathway or route depends on what other pathway does and thus giving an idea of division of labor among two reading paths working in parallel. Coltheart[21] proposed two dual theories about reading aloud (dual-route form print to speech DR-P) and reading comprehension (dual-route from print to meaning DR-M). The DRC model[14] provided the implementation of dual route theory based on general principle that words are recognized using two routes: 1) lexical route (orthographic to meaning) and 2) non-lexical route (orthographic to phonology to meaning). At first this distinction was drawn between words (which can be read by lexical route) and non-words (which cannot be read by lexical route and require the non-lexical route). The DRC model is based on the interactive-activation model[9] and in it's current form, it consists on three routes, the lexical semantic route, the lexical non-semantic route, and the GPC (grapheme to phoneme coding). Each route consists of a number of interacting layers. These layers contain sets of units and these units represent the smallest individual symbolic parts of the model, such as words in the orthographic lexicon or letters in the letter unit layer. There are two ways in which the units of different layers interact, inhibition and excitation. During inhibition the activation of a unit inhibits the activation of other units but in case of excitation the activation of a unit contributes to the activation of other units. Units may also interact on the same level through lateral inhibition.

Despite of all these models and debates some researchers argued that visual objects (words) are recognized by spatial frequencies rather than collection of visual features for example, Gervais et al.[22] showed that letter confusions are better predicted by spatial frequency rather than visual features. Allen[23] proposed the holistic model and suggested that words can be formed either via letter-level codes or via word-level codes in which the spatial frequency pattern of whole word is the basic unit of analysis. Recently, Allen[24] proposed a multistream model having a lexicon for decision about word recognition based on spatial frequency information. According to this model different channels are responsive to different aspects of stimulus, i.e. words are recognized from lower frequency components and letters are recognized from higher spatial frequency components. The word recognition process is tended to be based on holistic channel, however recognition can be based on information from analytical channels if stimulus information is unfamiliar.

In this study, we examined how letter permutation affects in visual recognition of words for two orthographically dissimilar languages. The purpose is to determine that how people can read permuted or jumbled text as proposed by a fake circulated statement on internet by September 2003 and noticed by Matt Davis. `http://www.mrc-cbu.cam.ac.uk/people/matt.davis/cmabridge/`

Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

This statement does not belong to University of Cambridge and does not have any theoretical standings. It is some how true that a human being, as a general pattern solver, is able to read permuted text but the underlying cognition of reading permuted and normal text is not same.

We present the hypothesis that recognition or reading of permuted and non-permuted words are two distinct mental level processes and people use different strategies in handling of permuted words as compared to normal words. We conducted three experiments in lexical decision tasks to analyze how reading is degraded or affected by letter permutation. These experiments were conducted in Urdu and German languages. In our lexical decision tasks, visual stimuli of common animal's names, in permuted and non-permuted forms, were presented to native speakers of Urdu and German languages. Speakers have to categorize these visual stimuli as birds or non-birds. A response time is recorded for each visual stimulus along with the reader's response.

2. OVERVIEW OF EXPERIMENTS

We conducted three lexical decision experiments in which we tested our hypothesis in reading of permuted and non-permuted words. The hypothesis testing is concerned with the relative response time latencies in which experimental participants decide whether the word that vary in order of its letter positions is bird or non-bird. We tested our hypothesis for Urdu and German languages by comparing the response time latencies and accuracy of responses for both permuted and non-permuted words. We used a longer exposure duration (5 sec) so that participants have sufficient time for word recognition. The stimulus words were permuted pseudo randomly by using normally distributed random numbers as new index value for each character in word strings. The permutation factor is controlled by a parameter sigma while keeping the first and last letter at its original position. The higher sigma value yields indexes with greater distance from its original location as compared to lower sigma. We used sigma is equal to 5 for pseudo random permutation of Urdu and German words. The first and last letters are assumed to have more importance in constituting the global word shape. Rayner[25] reported that change in the position of first or last letter of words in a sentence cause delays in reading in comparison with normal text (26% decrement in speed of reading for transposition of first letter and 36% decrement in speed of reading for transposition of last letter). The presented stimuli were the names of common animals which people had learned from their childhood. The words were either in permuted or non-permuted form and were randomly presented at the center of computer screen. Participants in each experiment had to response by pressing B for birds and N for non-birds. In every experiment participants were instructed to carry out the lexical decision task and these instructions were also displayed before the start of each experiment. All the participants were reported to have normal vision and they did not suffer any kind of dyslexia. In 1^{st} experiment we tested our hypothesis for Urdu language and in 2^{nd} and 3^{rd} experiments we tested our hypothesis for German language in uppercase and in noun-case (i.e. first letter in upper case and rest of letters in lower case). The 2^{nd} and 3^{rd} experiments were conducted simultaneously while order of experiments is shuffled for every participant to overcome the word familiarity effect.

Table 1. Characteristics of the Permuted and Non-permuted words Tested in Experiment 1 for Urdu Language.

	Non-Permuted				Permuted			
	Mean	Std	N	E%	Mean	Std	N	E%
	1.479051	0.888734	316	6.65	2.230606	1.311038	429	20.75
Syllables								
<3	1.480458	0.8947969	306	6.86	2.134011	1.254146	349	19.19
>=3	1.436	0.713461	10	0	2.652	1.470515	80	27.5
Letters								
<5	1.52625	0.9286	256	7.81	1.948228	1.098997	79	25.31
>=5	1.277667	0.6627175	60	1.66	2.294343	1.347529	350	19.71

2.1 1^{st} Experiment: Urdu Language

2.1.1 Method

Participants. 10 native speakers of Urdu language with mean age of 25 years participated in this experiment. All had normal vision or corrected to normal vision and did not have any kind of dyslexia.
Material. A set of 75 common names of animals in Urdu language were selected. The length of words ranged from 3-12 letter words. 43 animal names were pseudo randomly permuted keeping first and last letter at its original position.
Procedure. Each participant was tested on the individual basis in a quiet room. Word permutation and stimulus generation was done using a computer program developed by us in python† programming language. The stimulus presentation and response time calculation was done by integrating routines from psychopy library.[26] Stimuli were presented on center of computer screen with black background and white foreground in 36 points. Nafees Nastaleeq‡ font was selected to produce visual stimuli for Urdu language. Before start of each experiment detailed instructions were presented to each participant and participant had to start the experiment by pressing 'S' from computer keyboard. During experiment, after display of each stimulus a wait screen was presented. The next stimulus was presented when participant was ready for next stimulus and pressed any key from the keyboard. The participant heard a beep sound before display of each stimulus and after 1 sec delay next stimulus was displayed. Maximum exposure duration for each stimulus was 5 sec and after that the wait screen was appeared automatically. Participants responded to the stimulus by pressing 'B' for bird names and 'N' for non-bird names using two adjacent buttons of a standard computer keyboard. This response of a participant along with response time was recorded for each stimulus to analyze the recognition accuracy for permuted and non-permuted words.
Data Analysis. Data analysis and plotting of graphs were done using R§ package. Null responses (responses for which participant were unable to respond within 5 sec) were considered as wrong responses. We excluded the trials in which response time is less than 100 msec and response key is other than 'b' or 'n' from analysis. This resulted in exclusion of less than 1% of total response data. Primary analysis was to determine the recognition accuracy for permuted and non-permuted words and then to analyze response latencies for each kind of stimulus. Analysis was performed on whole set of data making two major groups (permuted, non-permuted) and then data was further grouped based on numbers of syllables and word length. We performed analysis of variance (ANOVA), distribution free rank test, and t-test to determine the significance differences in response time latencies for two classes of data. There were three factors in ANOVA: word type (permuted or non-permuted), number of syllables < 3 or ≥ 3 and word length < 5 or ≥ 5 for Urdu language.

2.1.2 Results

Table 1 shows the mean response time 'M', standard deviation 'Std', error percentage 'E%' and total numbers of samples 'N' for permuted and non-permuted words of Urdu language. For Urdu we divide the words based on numbers of syllables(< 3 and ≥ 3) and numbers of letters (< 5 and ≥ 5).

†http://www.python.org/
‡http://www.crulp.org/software/localization/Fonts/nafeesNastaleeq.html
§http://www.r-project.org/

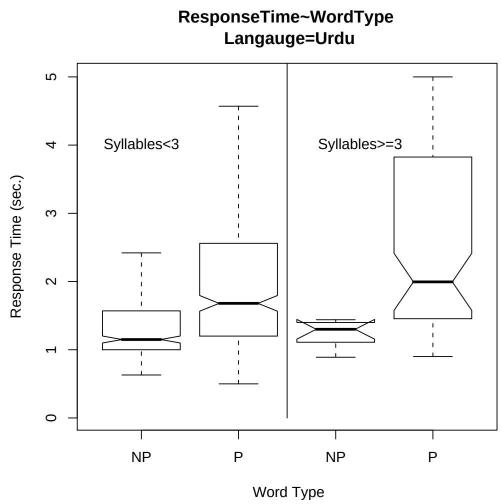

Figure 1. Box Plot of Response Times with Word Type and Numbers of Syllables. Permuted (P), Non-permuted (NP)

Response Time Analysis. There was significance difference in recognition of permuted and non-permuted words in Urdu. The participants took longer to recognize permuted words (M = 2.230606) than non-permuted words (M = 1.479051) $[F(1,9) = 79.656\ p < 0.0]$. There was main effect of numbers of syllables and word length in case of permuted words but there was no main effect of numbers of syllables in case of normal words. For permuted words the mean response time with < 3 syllables (M=2.134011) and ≥ 3 (M = 2.652) $[F(1,427) = 10.382\ p < 0.001]$. Difference in mean response time for permuted words having word length < 5 (M = 1.948228) and ≥ 5 (M = 2.294343) $[F(1,427) = 4.5291\ p < 0.01]$ also reflected the similar observation. This difference is also visible in box plot in figure 1 of permuted and non permuted words having < 3 or ≥ 3 syllabic units in a word. There were no significance effect of numbers of syllables $[F(1,314) = 0.0242\ ]$ and word length $[F(1,314) = 3.8371\ p < 0.05]$ for normal words.

Error Rate E%. Error rate showed that participants responded more accurately to normal words (E% = 6.65) than to permuted words (E% = 20.75). In case of permuted words the error rate was more for words having $\geq$ 3 syllables (E% = 27.5) as compare to words with < 3 syllables (E% = 19.19). The overall recognition accuracy is decreased by 31% for permuted words.

2.1.3 Discussion

The difference in mean response time latencies for responses of permuted and non-permuted words reflects a difference in reading behavior for permuted and normal words. This difference suggests the distinction in cognitive processing of permuted and non-permuted words in favor of our hypothesis. It can be concluded that people use direct route i.e. spellings to meaning in recognition of non-permuted words showed by fast response time and people use phonological mediated route (spelling to sound to meaning) in recognition of permuted words. The reason is that there is no direct visual pattern to map with mental lexicon and then phonology may help in recognition of this orthographically new pattern to map with some already familiar word as observed from delayed responses of participants for permuted words. Recognition accuracy and mean response time latencies is also significantly effected by numbers of syllables and word length for permuted words but this effect is not found in case of normal words. Error rate is significantly increased for permuted words in comparison with non-permuted words and this shows the significance of letter positions within a word.

2.2 2^{nd} and 3^{rd} Experiments: German Language, Uppercase and Noun-case

2.2.1 Method

Participants. 10 students from University of Kaiserslautern, Germany took part in this experiment. All of them had normal vision or vision was corrected to normal and were not had any kind of dyslexia. All were native

Table 2. Characteristics of the Permuted and Non-permuted words Tested in Experiment 2 for uppercase German.

	Non-Permuted				Permuted			
	Mean	Std	N	E%	Mean	Std	N	E%
	1.040733	0.4968834	440	1.36	1.683774	1.257993	460	10.21
Syllables								
<3	1.053082	0.5382642	320	1.87	1.457060	1.042060	310	7.41
>=3	1.007802	0.3641933	120	0	2.152315	1.514995	150	16
Letters								
<10	1.040346	0.5163229	390	1.53	1.489460	1.087656	380	7.63
>=10	1.043752	0.3091232	50	0	2.606762	1.573247	80	22.5

Table 3. Characteristics of the Permuted and Non-permuted words Tested in Experiment 3 for Noun-case German.

	Non-Permuted				Permuted			
	Mean	Std	N	E%	Mean	Std	N	E%
	0.9952255	0.5573976	440	2.27	1.571446	1.159749	460	10.22
Syllables								
<3	0.9736688	0.539243	320	1.87	1.395469	0.9602248	310	7.41
>=3	1.052710	0.60174	120	3.33	1.935130	1.426064	150	16
Letters								
<10	0.971344	0.5141068	390	2.05	1.387191	0.9390581	380	7.10
>=10	1.181501	0.8033287	50	4.0	2.446658	1.626399	80	25

speaker of German language with mean age of 24.3 years.

Material. A set of 90 common names of animals in German language were selected. The length of words ranged from 4-15 letter words. 46 animal names were pseudo randomly permuted.

Procedure. Exactly the similar procedure was adopted as in experiment 1 except that Times font was used for German words stimuli. Experiment 2 and 3 were conducted simultaneously, while shuffling the experiments for uppercase and noun-case for each participant.

Data Analysis. Data analysis and plotting of graphs was done similarly as in experiment 1 for uppercase and noun-case German words except that we used word length < 10 or ≥ 10 for German language. ANOVA was performed to compare the effect of case type for permuted and normal words.

2.2.2 Results

Table 2 and Table 3 shows the mean response time 'M', standard deviation 'Std', error percentage 'E%' and total nos of samples 'N' for permuted and non-permuted words for upper and noun cases of German language. Summary of response times was plotted in plot 2 with respect to numbers of syllables. We showed the ANOVA of uppercase with F_{upper} and of noun-case with F_{noun}. Mean response times and percentage of errors for uppercase and noun-case are shown as M_{upper}, E_{upper} and M_{noun}, E_{noun} respectively.

Response Time Analysis. Significance differences were found in mean response time latencies for German permuted and normal words for both uppercase and noun-case. The participants took longer to recognize permuted words (M_{upper} = 1.683774), (M_{noun} = 1.571446) than non-permuted words (M_{upper} = 1.040733), (M_{noun} = 0.9952255) [$F_{upper}(1,9) = 59.515$ $p < 0.0$],[$F_{noun}(1,9) = 66.536$ $p < 0.0$]. There was main effect of numbers of syllables and word length in case of permuted words for upper and noun-case. For permuted words the mean response time with < 3 syllables (M_{upper}=1.457060), (M_{noun}=1.395469) and ≥ 3 (M_{upper}= 2.152315), (M_{noun}= 1.935130) [$F_{upper}(1,458) = 33.031$ $p < 0.0$], [$F_{noun}(1,458) = 22.934$ $p < 0.0$]. Difference in mean response times for permuted words having word length < 10 (M_{upper} = 1.489460), (M_{noun} = 1.387191) and $\geq$ 10 (M_{upper} = 2.606762), (M_{noun} = 2.446658) [$F_{upper}(1,458) = 58.683$ $p < 0.0$], [$F_{noun}(1,458) = 62.548$ $p < 0.0$] were also reflected the similar observation. This difference is also visible in box plot in figure 2 of permuted and non permuted words having < 3 or ≥ 3 syllabic units both for upper and noun cases. There was no main effect of numbers of syllables [$F_{upper}(1,438) = 0.3952$], [$F_{noun}(1,438) = 0.1856$] and word length [$F_{upper}(1,438) = 0.0021$], [$F_{noun}(1,438) = 6.3772$ $p < 0.05$] in case of normal words.

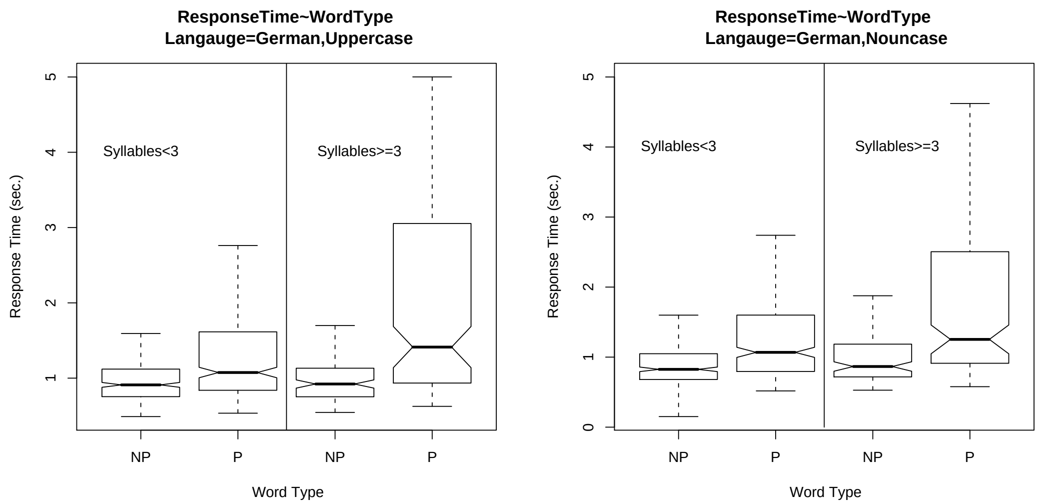

Figure 2. Box Plots of Response Times with Word Type and Numbers of Syllables. Permuted (P), Non-permuted (NP)

Individual Alphabets	Urdu Non-Permuted Words	Urdu Permuted Words	English Translation
د ر ی ا ی ء گ ھ و ڑ ا	دریائُ گھوڑا	د گریُوڑھیاا	Hippopotamus
چ ی و ن ٹ ی خ و ر	چیونٹی خور	چیونخ ٹیور	Anteater
ب ا ر ہ س ِ ن گ ھ ا	بارہ سِنگھا	بھانسرھِگ ا	Stag
ک ی ن گ ر و	کینگرو	کینرگو	Kangaroo

Figure 3. Example urdu words with permuted, non permuted forms and individual alphabets.

Error Rate E%. Error rate showed that participants responded more accurately to normal words ($E_{upper}\% = 1.36$, $E_{noun} = 2.27$) than to permuted words ($E_{upper}\% = 10.21$, $E_{noun}\% = 10.22$). In case of permuted words the error rate was more for words having ≥ 3 syllables ($E_{upper}\% = 16$, $E_{noun}\% = 16$) as compared to words with < 3 syllables ($E_{upper}\% = 7.41$, $E_{noun}\% = 7.41$). Similarly, recognition error was greater for words having numbers of letter ≥ 10 ($E_{upper}\% = 22.5$, $E_{noun}\% = 25$) than words with word length < 10 ($E_{upper}\% = 7.63$, $E_{noun}\% = 7.10$). The overall recognition accuracy is decreased by 11% in case of permuted words.

2.2.3 Discussion

We get similar results for both, uppercase and noun-case of German words, as we achieved for Urdu language. Phonological mediated pathway is assumed to be activated in case of German permuted words irrespective of case whereas a direct route is found to be activated for recognition of normal German words as reflected by the mean response time delays. It is observed from mean response time delays that noun-case words were recognized faster than uppercase words in both permuted and non-permuted forms, resulted in favor of word shape models.

3. GENERAL DISCUSSION

The difference in mean response time latencies for permuted and non-permuted words reflects a difference in reading behavior for permuted and normal words. It is observed that people showed similar behavior for two orthographically different languages i.e. people are slower and made more errors in visual word recognition of permuted words in comparison with normal words. This observation leads towards the similarity behind the cognition of reading for two different languages. Therefore, it can be concluded from the results of this study that people are able to read permuted text, but reading of permuted and normal text are two distinct mental level activities. These two high level cognitive processes can be best explained with the help of dual rout theories of reading aloud and recognition. According to these theories, skilled readers use a direct route or lexical semantic route to read and comprehend regular and high frequency words. This route works by direct mapping of orthographic patterns or spellings to sound or meaning and therefore this route is considered to be fast. However, readers use an indirect route or phonological mediated route for recognition of exceptional words or low frequency words resulting in a slow, long pathway from orthography to phonology to meaning.

It is also observed that reading of Urdu is comparatively slower than reading of German (uppercase as well as noun-case) in both permuted and non-permuted forms. In case of normal words, the mean response times of Urdu (M = 1.479051) and German (M= 1.040733, M = 0.9952255) represent a significance difference in reading. This difference can be due to the characteristics of Urdu language like it is written from right to left, characters have connections to each other to form a word and some characters have special symbols called diacritics above or below. Individual letters of Urdu lost their basic shape when they merge with other letters to form a word. The shape of each letter is also depends on its position (start-middle-end) within the word. Figure 3 shows the shape variation of individual letters of Urdu in permuted and non-permuted forms. These characteristics show that there can be a possibility of division of labor[18] among two working components of brain (orthography and phonology) and in case of Urdu, orthography to phonology to meaning components may be more activated as compared to orthography to meaning components, resulting in delay of visual word recognition even for normal words.

Another possibility for delay in recognition of Urdu words can be due to Nafees Nastaleeq font. In Urdu, reading is highly dependent on font type and Nafees Nastaleeq is considered to be a rather slow font for reading. We also plan to conduct a study to see the impact of different fonts in reading of Urdu words.

The error rate in recognition of Urdu permuted words is significantly increased with increase of number of syllables or increase in word length. This observation reflects the significance of global shape in visual recognition of words. As stated earlier, Urdu belongs to cursive script and shape of each character in Urdu is highly sensitive to its position in a word (start, middle, end). When words of Urdu language are permuted there is an overall change in the global shape of the word. Therefore more numbers of syllabic units or numbers of letters in a word caused more shape degradation. This shape degradation resulted in difficulty of reading permuted words that have more number of letters or syllables, as clearly visible by results. The effect of global word shape is also observed in reading of noun-case and uppercase German words. It can also be inferred that individual letter positions have significance impact on reading and change of letter positions within a word makes it difficult to read and understand, resulting in a change of the strategy to read permuted words.

The results obtained in this study are also in accordance with the presence of Visual Word Form Area (VWFA)[27] in the rear left-hemisphere occipital lobe to recognize familiar words and phonological processing besides the visual word recognition of words and anagrams.[28]

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