Is There Flexibility in Letter-Position Encoding in Hindi? Evidence from Masked Form Priming Study

Suraj Kumar (surajk22@iitk.ac.in)
Department of Cognitive Science, Indian Institute of Technology Kanpur,
G66M+W5J, Kalyanpur, Kanpur, 208016, Uttar Pradesh, India

Anurag Khare (akhare@iitk.ac.in)
Department of Cognitive Science, Indian Institute of Technology Kanpur,
G66M+W5J, Kalyanpur, Kanpur, 208016, Uttar Pradesh, India

Ark Verma (arkverma@iitk.ac.in)
Department of Cognitive Science, Indian Institute of Technology Kanpur,
G66M+W5J, Kalyanpur, Kanpur, 208016, Uttar Pradesh, India

Abstract

Recognizing written words involves identifying individual letters, as well as keeping track of specific positions of the letters. Interestingly, some languages show flexibility in letter-position encoding which is inferred by the observation that pseudowords formed by transposing internal letters of a word (e.g., jugde-JUDGE) can facilitate recognition of the given word. While research in English and other Indo-European languages have shown that readers can cope with such violations in the canonical order of letters in a word, research from other languages such as Arabic, Hebrew, and Korean show contrasting results. Such scenario creates a need of more research from different writing systems of the world, so that a universal model of word-recognition can be built. Therefore, in the current study, we investigated flexibility in letter-position encoding in Hindi (*Devanagari script)*. Interestingly, we found evidence for flexibility in letter position encoding in Hindi similar to English and other Indo-European languages.

Keywords: word-reading; letter position encoding, flexibility, TL priming effect, Lexical decision task, same-different task

Introduction

Successful recognition of visual words depends upon two critical skills, i.e., identifying specific letters in a given word which helps to distinguish between similar words such as cat, bat, mat rat, hat etc., and identifying the specific positions of letters within any given word, which would help us distinguishing between similar words such as PEST vs. STEP, or PART vs. TRAP. Initial theories and models of word recognition such as the Interactive Activation Model (McClelland & Rumelhart, 1981), the Dual Route Cascaded Model of word reading (Coltheart et al., 2001) or the Multiple Read-Out Model (Grainger & Jacobs, 1996) assumed slot-based coding schemes for letter positions, which assumed position-specific encoding for letters, under which a nonword created by transposing two adjacent letters of a word for e.g. JUGDE would be considered as dissimilar to the word JUDGE as a nonword creating by simply replacing those letters, JUNPE. However, more recent research has shown that nonwords created by transposing two adjacent letters of a word were likely to facilitate reading of the base words such as JUGDE → JUDGE more than nonwords produced through replacement or substitution such as JUPTE → JUDGE (Lupker et al., 2008; Perea & Lupker, 2003a, 2003b; Schoonbaert & Grainger, 2004). This finding has been referred to as the Transposed – Letter Priming effect (TL-Priming) which has been demonstrated with English and other Indio-European languages which use the Roman alphabet and few such as Thai (Winskel et al., 2012) and Japanese (Perea & Perez, 2009). However, they consistently been absent from other languages such as Hebrew (Velan & Frost, 2007, 2009b, 2011) and Arabic (Perea et al., 2010).

An interesting observation has been that these findings are observed regardless of tasks involving lexical processes (such as, Lexical decision task; LDT) or prelexical processes (such as, Same-Different task; SD) (Kinoshita & Norris, 2009a, 2009b, 2013; Norris & Kinoshita, 2008, 2012; Perea & Lupker, 2003b, 2003a, 2004). Interestingly, there have been contrasting findings for some languages depending upon the tasks that have been used to investigate the TL priming effects. For example, in Hebrew language, Velan & Frost (2007) did not find TL priming effects with LDT task, but Kinoshita et al. (2012) found TL priming effects with SD task. Similarly, in Arabic language, Boudelaa et al. (2019) did not find TL priming effect in a LDT task (exp 1), but found a robust TL priming effect in a SD task (exp 2). Similarly, in Korean language, Rastle et al. (2019) did not observed TL priming effects with LDT task, but Lee et al. (2021) found TL priming effects with SD task. Consequently, researchers have concluded that letter position encoding, a constituent skill of reading is not universal and must adapt to the specifics of various writing systems (Frost, 2012). Such a position necessitates conducting similar research in different languages across various writing systems (Rastle et al., 2019).

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The case of Hindi: *Devanagari script*

In the current study, we seek to investigate flexibility in letter position encoding in Hindi, which is written using the Devanagari script, a derivative of the ancient Brahmi script (Bright, 1996). Devanagari is referred to as an *aksharic* writing system, wherein an *akshar* is supposed to transcribe a [Cv] syllable wherein C depicts a consonant unit, and v refers to a vowel unit, also referred to as the schwa (an inherent vowel embedded in the consonant unit and is often unpronounced). The vowel V is often represented all by itself as well sometimes as a *matra* M unit which are vowel diacritics that are used to modify the C units by adding the vowel sound and therefore forming the CM unit (for a more detailed discussion see Rimzhim et al., 2013, 2020). Given the relatively unique features of the Devanagari script used to denote Hindi, as opposed to the Roman script used to denote English and other Indo-European languages, it is worthwhile investigating flexibility in letter position encoding in Hindi. Till date only a couple of studies (Rao et al., 2012; Rimzhim et al., 2020) have approached the issue in Hindi and have concluded that Hindi displays flexibility in letter position encoding much like the alphabetic scripts like that of English.

More specifically, Rimzhim et al. (2020) has investigated the influence of these three different types of transpositions on target recognition, i.e., the transposition of consonant units, [C], hereafter referred to Letter units [L] *matras* [M] or consonant + matra [C+M]/[L+M] units. However, Rimzhim et al., (2020) used a simple unprimed lexical decision task and the stimuli set were not derived from a standardized corpus or frequency-controlled corpus. In order to address the potential limits in the scope of the previous study, in the current study we manipulate letter-only, matra only, and letter + matra transpositions, to investigated flexibility in letter position encoding in Hindi language. We also manipulated frequency of the target words to test whether flexibility in letter position encoding is influenced by word frequency or not in Hindi language. Finally, we decided to use both a masked priming Lexical Decision Task (LDT) (Experiment 1) as well as the Same-Different (SD) task (Experiment 2). Drawing from the findings of the study previously done by Rimzhim et al. (2020) with simple unprimed lexical decision task, we hypothesized TL priming in Hindi language regardless of the type of manipulation.

Experiment 1

Method

Participant. We estimated the required sample size (using the G-power software (version 3.9.1.7) of 54 (with medium effect size of Cohen's f = 0.30, α = 0.05, power = 0.95) to detect a significant effect (Erdfelder et al., 1996). However, in order to avoid conditions such as loss of data due to inaccuracy etc., sixty-four participants (mean age: 25.87 years, SD: 5.37) participated in this experiment. All participants were native speakers of Hindi language and had completed their education in Hindi medium till senior secondary level or higher. All participants were right-handed with normal or corrected-to-normal vision and had no history of any learning disorder. Their handedness was assessed using the revised short version of the Edinburgh Handedness Inventory (Veale, 2013). All of them were compensated for their time, and the study was approved from the institutional ethics committee at the Indian Institute of Technology Kanpur.

Task, design, and stimuli. We used the masked form priming Lexical Decision Task in the current experiment. This task is widely used in the available literature to address flexibility in letter position encoding (Boudelaa et al., 2019; Layes et al., 2019; Perea & Lupker, 2004; Perea & Rosa, 2002; Velan & Frost, 2007, 2009a). The design was a 3 (Manipulation-type) * 3 (Prime-type) * 2 (Frequency) factorial design. The levels of the factor Manipulation-Type were: (1) Letter-only manipulation, (2) Matra-only manipulation, and (3) Letter + Matra manipulation. The levels of the factor Prime-type were: (1) Identity prime, (2) Transposed-letter prime, and (3) Replaced-form prime. The Replaced form prime was used as the control condition prime. Lastly, the levels of the factor Frequency were: (1) Low, and (2) High.

The stimuli consisted of 180 word targets, and 180 non-word targets. These targets were selected from the recently developed 'Shabd' corpus (Verma et al., 2021). Out of the 180 word targets, 90 targets were low frequency (1-3 Zipf), and the other 90 were the high frequency (3-6 Zipf). We avoided abbreviations, proper nouns, and compound nouns. The targets consisted of 4 letters only with either 0-matra or 1-matra (for example: 4 letter 0 matra: अवसर; and 4 letter 1 matra: सहोदर). Each target was paired with three different non-word primes. For example, for 4-letter 0-matra target (e.g., अवसर), the primes were: (1) Identity prime (अवसर), (2) Transposed-letter prime (असवर), and (3) Replaced-form prime (अगमर). For the 4-letter 1-matra target (e.g., सहोदर), the primes were: (1) Identity prime (सहोदर), (2) Transposed-letter prime (सहदोर), and (3) Replaced-form prime (सपनुर). The non-word targets were created using a Python code which made sure that the strings are selected randomly, and that there were no repetitions. Three experimental lists were constructed using a Latin-Square design technique so that each target appeared only once in each set, but each time in a different priming condition.

The overall experiment consisted of two blocks of trials consisting of 180 trials in each block. Each block consisted of entirely new set of target stimuli. Any target stimuli used in one block was not used in another block. Each target stimuli with the prime were used only once. We also counterbalanced the response keys by making two different versions of each list. One version consisted of 'm' key as correct response and 'z' key as incorrect response, whereas another version consisted of 'z' key as correct response and 'm' key as incorrect response. This was done for all the three lists, and each list was sent to separate different participants.

The overall experiment was designed in PsychoPy (version 2021.1.2) and was run online via Pavlovia (Peirce et al., 2019). Please note that recently it has been established that online experiments using Pavlovia produce same results as offline masked priming experiments (see: (Angele et al., 2022)).

Procedure The procedure of this experiment was similar to other studies which used LDT task to investigate flexibility in letter position encoding issue (e.g., Perea & Lupker, 2003; Boudelaa et al., 2019, Rastle et al., 2019). Each trial began with a central fixation for 200 ms, after which five hash marks were presented for 500 ms, followed by the prime presented for 50 ms, then the target was presented until response or 2000 ms. The inter-trial interval was 1000 ms. The overall trial structure is shown in figure 1 below. It is to note here that unlike in Roman languages, Hindi does not have 'lowercase' or 'uppercase' formats. So, to reduce perceptual overlap between primes and targets we reduced the letter heights of primes targets, on the lines of Rastle et al. (2019) for the Korean study; we presented primes with the letter height of 0.04, while the targets with the letter height of 0.07. Participants were instructed to respond to the target as quickly as possible by pressing 'M' key on their keyboard if the target was a valid Hindi word, or 'Z' key if the target was not a valid Hindi word. The counterbalancing of keys was also done. The trials were presented in different random order for each participant and were preceded by 36 practice trials before the beginning of the experiment. The overall experiment took 20-25 minutes to finish with regular breaks between the blocks. After completion of the experiment, all the participants were compensated for their time with an amazon gift card worth 50 Indian rupees.

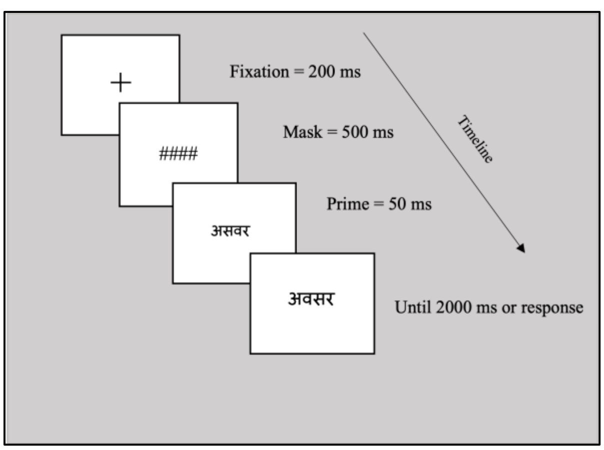

Figure 1. Trial diagram of experiment 1 (LDT task).

Results

Data cleaning and analysis protocol was followed very closely to Boudelaa et al. (2019) and Rastle et al. (2019). For cleaning the data, we first calculated the percentage accuracy of individual participants, and included only those participants' data in analysis who had percentage accuracy more than 70%. This was done similar to Boudelaa et al. (2019) and Rastle et al. (2019) to ensure less artifacts in the data. This resulted in the removal of six participants' data. Further, we removed the incorrect responses, unattempt responses, and response times less than 200 ms, and greater than 1800 ms (similarly as done in Boudelaa (2019)). This resulted in the removal of 4.8% of the total data. To do all the analysis reported here, we used Linear mixed effects modelling (LMM) approach to analyze the reaction time data, and logistic mixed-effects regression to analyze the error data. We implemented these models in R (Version 4.3.2), and used lme4 package (Bates et al., 2015). We used 'lmerTest' package (Kuznetsova et al., 2017) in R to calculate the degrees of freedom and *p*-values using Satterthwaite's approximation. We analyzed the responses for word and non-word targets separately as done in Perea & Lupker (2004) and more recently in Boudelaa et al. (2019). We compared all priming effects by taking identity prime condition as the baseline. In each of these cases, assumptions of the Linear mixed models were met by doing log transformation of the RT data.

Word data. For the word analysis data, we sought to identify if there was an effect of Prime-type, Word-frequency, and Manipulation type on recognition of targets. Therefore, we included these as fixed factors along with List in the model. 'Participants', and 'Items' were included as random factor in the model. For RT analysis, the maximal structure was defined as: lmer (RT ~ Prime-type * Word-frequency * Manipulation-type + List + (1|Subject) + (1|Item). Results showed a main effect of Prime-type $F(2, 8829.4) = 14.19$, $p < .007$. A main effect of word-frequency was also found, $F(1, 218.2) = 32.39$, $p < .004$. However, there was no interaction between prime-type and word-frequency. There was no main effect of Manipulation-type, but there was an interaction between frequency and Manipulation-type $F(2, 219.7) = 8.16$, $p < .003$.

Post-hoc analysis for frequency showed that reaction time for high frequency word targets were significantly faster (mean = 812 ms) than those of the Low frequency word targets (mean = 873 ms) (*estimate*, $\beta = -61.1$, $SE = 10.5$, $z = -5.801$, $p < .001$). Post-hoc analysis for prime-types showed that reaction time for identity prime condition (mean = 834 ms) and transposed prime condition (mean = 835 ms) were significantly faster than replaced form prime condition (mean = 859 ms) (ID-RL: $\beta = -24.383$, $SE = 5.72$, $z = -4.26$, $p < .001$, and TL-RL: $\beta = -24.196$, $SE = 5.73$, $z = -4.22$, $p < .001$). There was no significant difference between identity and transposed prime conditions; $\beta = -0.187$, $SE = 5.72$, $z = -0.03$, $p = .99$). Post-hoc for frequency and manipulation type interaction showed significant difference only for high frequency Letter-only and matra-only conditions $\beta = 78.11$, $SE = 19.0$, $z = -4.10$, $p = .0006$. There was no three-way interaction among the variables.

Error analysis was done using logistic mixed-effects regression. The maximal structure was defined as glmer (Error Rate ~ Prime-type * Word-frequency * Manipulation-type + List + (1|Subject) + (1|Item), family = binomial). Results showed a that error rates were lower for high frequency condition compared with Low frequency condition (intercept: $\beta = 2.72$, $SE = 0.34$, $z = 7.85$, $p < .001$). For prime-types, accuracy for Replaced prime types ($\beta = -0.10$, $SE = 0.19$, $z = -0.07$, $p = .94$), and Transposed prime types ($\beta = -0.08$, $SE = 0.19$, $z = -0.42$, $p = .66$) did not from significantly from the Identity prime types. No other factor or interaction were significant.

Non-word data. There were virtually no differences across the different priming conditions in either the latency or error data ($p > 0.05$ for all conditions). These results are like that of Perea & Lupker, 2004) (exp 1). Table 1 below summarizes the mean latencies and error rates for the given conditions.

Table 1. Mean Lexical Decision Response Latencies (RT, in millisecond) and percent error rates (in parentheses) in exp 1.

Prime-condition	Manipulation-type	Target-type		
		Word		Non-word
		High frequency	Low frequency	
Identity	Letter only	827.84 (.15)	844.50 (.14)	1005.41 (.19)
	Matra only	777.40 (.04)	878.26 (.11)	939.99 (0.14)
	Letter + matra	808.71 (.06)	887.03 (.12)	916.08 (.07)
Transposed	Letter only	830.75 (.16)	857.31 (.14)	999.05 (.19)
	Matra only	774.80 (.04)	869. 06 (.14)	941.49 (0.13)
	Letter + matra	821.79 (.04)	871.95 (.15)	904.77 (.07)
Replaced	Letter only	871.28 (.15)	890.24 (.15)	1002.59 (.20)
	Matra only	786.57 (.02)	919.90 (.12)	919.54 (0.16)
	Letter + matra	818.97 (.07)	890.28 (.13)	901.60 (.07)

Discussion The results from the lexical decision task show that participants were equally faster for words preceded by the identity & TL-primes as opposed to the replaced form primes. These effects are in line with those reported by Rimzhim et al., (2020). Interestingly, the effects are clearer for high frequency words, although given that there is no effect of manipulation type, one could conclude that participants are able to cope with transpositions not only at the Letter level but also at the levels of Matra and also Letter + Matra transpositions. Given these effects of flexibility in letter position encoding during lexical access, the authors were curious to investigate whether the phenomena also manifest at the prelexical level using the same – different task, as depicted in other studies (e.g., Kinoshita & Norris, 2009).

Experiment 2

Method

Participant. Sixty-two participants (mean age: 24.4 years, SD: 5.34) participated in this experiment. The other characteristics of participants were similar to experiment 1. However, in this experiment, we chose entirely new set of participants to make sure that there will be no repetition effects. This experiment as well as the participants were entirely different compared to experiment 1.

Task, design, and stimuli. We used the Same-Different task for the current study. This task is widely used in the literature to investigate prelexical processing in visual word recognition (Boudelaa et al., 2019; Kinoshita et al., 2012; Kinoshita & Norris, 2009a; Lee et al., 2021a). The design was similar to experiment 1. The stimuli for this experiment were same as that of experiment. Out of the 180 word-targets, we divided half to be referent for the same condition, and another half to be referent for the different condition. Similarly, for the non-word targets. This was done across conditions. Similar to experiment 1, three experimental lists were constructed so that each target appeared only once in each set, but each time in a different priming condition. These participants were randomly assigned to each list.

Procedure. The procedure of this task closely followed those of Kinoshita et al. (2012), and Lee et al. (2021). Each trial began with a central fixation for 200 ms, after which a reference item above the forward mask of four hash marks appeared for 1000 ms and then disappeared. The forward mask was immediately replaced by a prime for 50ms, after which the target stimuli appeared for 2000 ms or until response whichever was faster. The inter-trial interval was 1 second. The overall trial structure is shown in figure 2 below.

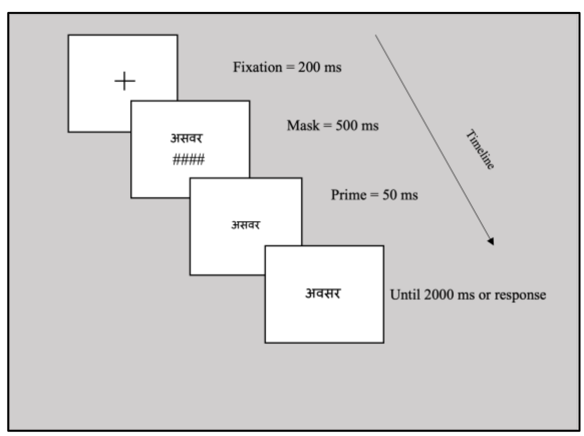

Figure 2. Trial-diagram of experiment 2 (SD task).

Results

Cleaning of data followed the same procedure as experiment 1. We first calculated the percentage accuracy of individual participants, and included only those participants' data in analysis who had percentage accuracy more than 70%. This resulted in the removal of seven participants' data. We removed the incorrect responses, and response times less than 200 ms or greater than 1800 ms. This resulted in the removal of 3.9% of the total data. Protocol of analysis and model-fitting was followed closely with Lee et al. (2021). Like other previous studies, we also report analysis for only 'SAME' trials, as only SAME trials show masked priming effects (Kinoshtia et al. (2012), Lee et al. (2021)).

RT data was analyzed using generalized linear mixed effects models with lme4 package (Version 1.1.33, Bates et al., 2015) in R (Version 4.3.2; R core Team, 2016). The RT data was analyzed using two generalized linear mixed-effects models as done in Lee et al. (2021). RTs were also log transformed to meet the assumptions of the mixed models. All the comparisons were done by taking identity prime condition as baseline. The maximal structure of this model was defined as: lmer (RT ~ Prime-type * Target-type * Frequency * Manipulation-type + List + (1|Subject) + (1|Item). Results showed a main effect of Prime-type $F(2, 9293.0) = 6.57$, $p < .001$, and Target-type $F(1, 174.5) = 77.48$, $p < .001$. There were no main effects of Frequency or Manipulation-type. However, there was an interaction between Target-type and Manipulation-type. P

Post-hoc analysis for Target-type showed that RTs for word targets were significantly faster (648 ms) than non-word targets (680 ms) (*estimate*, $\beta = 31.3$, $SE = 3.84$, $z = -8.153$, $p < .001$). Post-hoc analysis for Prime-type showed that RTs for identity prime condition were significantly faster (660 ms) than RL prime condition (672 ms) ($\beta = -11.64$, $SE = 4.37$, $z = -2.67$, $p < .02$). Furthermore, RTs for TL prime condition was significantly faster (661 ms) than RL prime condition (672 ms) ($\beta = -10.89$, $SE = 4.36$, $z = -2.49$, $p < .03$). There was no significant difference between RTs for identity and TL prime conditions ($p = .98$). Post-hoc analysis of Target-type and Manipulation-type interaction showed significant difference only for non-word letter-plus-matra to non-word matra-only Letter-only conditions ($\beta = 20.71$, $SE = 6.68$, $z = 3.10$, $p = .02$). There was no three-way interaction among the variables.

Error analysis was done using logistic mixed-effects regression. The maximal structure for the first model was defined as glmer (Error Rate ~ Prime-type * Target-type * Frequency * Manipulation-type + List + (1|Subject) + (1|Item), family = binomial). Results showed that responses for identity primes were significantly more accurate than TL or RL prime conditions ($\beta = 3.24$, $SE = 0.24$, $z = 13.26$, $p < .001$). There was no significant difference between the TL and RL prime conditions. Furthermore, no interactions were significant. Table 2 summarizes all the RTs and error rates.

Table 2. Mean Response Latencies (RT, in ms), percent error rates in parentheses in exp 2 (Same-Different task).

Prime-condition	Manipulation-type	Target-type		
		Word		Non-word
		High frequency	Low frequency	
"Same" responses				
Identity	Letter only	642.94 (0.03)	645.14 (0.07)	671.02 (0.04)
	Matra only	638.23 (0.02)	640.72 (0.03)	663.16 (0.03)
	Letter + matra	639.54 (0.03)	646.85 (0.04)	682.81 (0.05)
Transposed	Letter only	645.93 (0.05)	643.51 (0.05)	689.21 (0.06)
	Matra only	639.31 (0.02)	652.84 (0.03)	656.14 (0.03)
	Letter + matra	622.94 (0.01)	644.59 (0.01)	679.13 (0.03)
	Letter only	645.14 (0.07)	671.88 (0.07)	692.22 (0.05)
	Matra only	654.18 (0.03)	651.40 (0.02)	670.83 (0.03)
Replaced	Letter + matra	647.24 (0.02)	663.09 (0.02)	689.06 (0.06)
"Different" responses				
	Letter only	711.24 (0.03)	717.53 (0.05)	726.08 (0.05)
	Matra only	705.32 (0.05)	702.62 (0.03)	717.24 (0.03)
Identity	Letter + matra	703.84 (0.02)	692.25 (0.01)	704.59 (0.04)
	Letter only	720.68 (0.06)	702.05 (0.03)	731.30 (0.04)
	Matra only	723.69 (0.02)	717.30 (0.4)	708.80 (0.03)
Transposed	Letter + matra	713.79 (0.04)	692.72 (0.03)	707.87 (0.03)
	Letter only	731.43 (0.05)	713.66 (0.03)	706.55 (0.03)
	Matra only	726.00 (0.04)	736.80 (0.03)	707.27 (0.04)
Replaced	Letter + matra	713.32 (0.04)	700.33 (0.02)	701.90 (0.01)

Discussion As with the previous experiment, participants were faster and more accurate for identity & TL-primes as opposed to the replaced prime conditions. These results are consistent with (Kinoshita et al., 2012) and (Duñabeitia et al., 2009). Also, consistent with previous results the flexibility for letter position encoding persisted across the different types of manipulation and irrespective of word frequency.

General Discussion

Findings from both these experiments show robust TL priming effects. To elaborate, responses for target identification in transposed letter prime were significantly faster than replaced form prime condition but not with identity prime condition in both the experiments. This shows flexibility in letter position encoding in Hindi language which is written in Devanagari orthography. In other words, the readers of Hindi language can cope up with violations in the canonical order of letters. Importantly, this flexibility is independent of word-frequency or type of manipulations (i.e., letter-only, matra-only, or letter-plus-matra transpositions). This shows that encoding of letter position happens more like alphabetic languages such as English or other European languages such as Spanish or French.

As mentioned earlier, our results are in line with Rimzhim et al. (2020), wherein the authors had manipulated letter-only, matra-only, or letter-plus-matra transpositions and tested for transposition effects. They had used a simple unprimed lexical decision task in which no priming was done. They findings also that the different grouping of letters based on letter-only, matra-only, or letter-plus-matra transpositions did not prevent the readers from flexibly encoding the letter position. Therefore, the authors had concluded that letter position in Hindi language is encoded more like alphabetic languages. In the current study, after controlling for potential confounding factors (such as selection of stimuli from a standardized corpus or frequency-controlled corpus), we found similar effects with both LDT and SD priming tasks.

Our findings are different from other languages (such as Hebrew, Arabic, and Korean) which do not belong to Indo-European languages family (Boudelaa et al., 2019; Kinoshita et al., 2012; Lee et al., 2021a; Rastle et al., 2019b; Velan & Frost, 2007). In these languages, TL priming effects were found only with SD task, and not with the LDT task whereas in our study TL priming effects are found with both tasks. This shows that whereas flexibility in these languages happen only at the prelexical level and not in the lexical level, in Hindi languages flexibility occurs at both prelexical and lexical levels. These findings put challenges for the current models of visual word recognition which evidently need to incorporate findings from languages using different writing systems derived from different orthographic families.

However, we must admit that future studies in Hindi need to specifically test the predictions of different models of letter position encoding, such as the SERIOL (Whitney, 2001) and the SOLAR models (Davis, 2001; Davis & Bowers, 2006). It would be interesting to note whether the predictions of these models would be applicable to the Devanagari script, given its nuances in the form of vowel diacritics (*matras*) and other idiosyncrasies. If the current study or that of Rimzhim et al., (2020) are to be followed one would be inclined to assume that letter position encoding in Hindi follows similar rules that are followed in alphabetic languages like English, wherein the *aksharas* are analogous to the letter units in these languages. More research in Hindi as well as in other Indian languages is expected to bring clarity in the direction and add more to the understanding of letter position encoding as a constituent process of word reading.

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